IMPACTS OF SMART CITY DEVELOPMENT: EXPERIENCE OF SOUTH KOREA

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Impacts of Smart City Development: Experience of South Korea

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Impacts van Smart City Ontwikkeling: Ervaring met Zuid-Korea

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Summary

Smart cities aim to achieve urban sustainability and high quality of life through the active use of information and communication technologies (ICT). There is a lofty aspiration for the smart city concept, and many cities already initiated smart city projects. South Korea started smart city development in the early 2000s as one of the national development strategies. More than 50 cities are claiming to be smart since the municipalities initiated smart city projects. To this end, some questions arise. What are the impacts of smart city development? What are the empirical impacts of smart city development in economic, environmental, social, governance, and technological dimensions? Is there a difference in performance between smart cities and non-smart cities?

Chapter 1, the introduction, explains the background and purpose of this research. The background provides the emergence and evolution of the smart city concept. Followed by is the problem statement that identifies the research gap. Smart city literature mainly focuses on concepts, operations, and technological design, but few empirical studies on smart city development impacts. The main research question is: What are the impacts of smart city development on urban sustainability? This research question is divided into four sub-research questions:

1) How does the current smart city literature portray the impacts of smart city development?
2) What are the overall empirical impacts of smart city development on urban sustainability?
3) What are the empirical impacts of smart city development on environmental sustainability, especially the energy transition?
4) What are the empirical impacts of smart city development on governance?

The last two questions give attention to smart city development's environmental and governance aspects, which had less focus from academia. The smart city concept is introduced in detail, first comparing with relevant concepts such as digital city, intelligent city, and information city and studying smart cities' definitions and characteristics. The rest of Chapter 1 notes the significance of the study and the composition of the thesis.

From Chapter 2 to Chapter 5 are the four articles, each answering the sub-research questions. Chapter 2 is the first paper, 'Identifying the results of

smart city development: findings from a systematic literature review.' This article dedicates to collect the impacts that are scattered in smart city literature. It uses a systematic literature review method to qualitatively analyze how current literature portrays impacts of smart city development. Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) protocol is used to identify and analyze the articles. For eligibility criteria, field of study, topic, research method, language, publication status and database, and publication year are considered. Articles are collected from Scopus and the Web of Science. Based on the prescribed criteria total of 55 articles are selected for analysis. Two standards are used to categorize the impacts: 1) positive or negative, and 2) hypothetical or observed based on the empirical evidence suggested in each article.

The analysis revealed 12 positive impacts and four negative impacts that are frequently mentioned in the papers. In order of frequency, identified positive impacts are 1) facilitating economic development, 2) increasing efficiency of public services, 3) enhancing citizen involvement, 4) increasing quality of life, 5) protecting environment, 6) facilitating social development, 7) facilitating good governance, 8) empowering citizens, 9) facilitating sustainable development, 10) foster innovation, 11) enhancing cooperation, and 12) increasing social capital. Among these positive impacts, 3), 5), 6), 9), 10), 12) were purely hypothetical without empirical evidence. There is relatively less attention to negative results. The negative impacts are 1) aggravating/hiding exiting urban problems, 2) polarization & inequality, 3) privacy & security issues, and 4) diminishing freedom of speech & democracy. Among these negative impacts, 3) and 4) were purely hypothetical. Also, positive impacts are highlighted in high-income countries, while the negative impacts are emphasized in middle-income countries. There were no case studies of low-income countries.

Chapter 3 is the second paper, 'Smart city impact index: finding empirical evidence on the impacts of smart city development.' It first develops indicators for positive and negative impacts found in Chapter 2, which requires a review of the literature and existing evaluation methods. The impacts are categorized with four pillars of sustainability (economic, environmental, social, and governance) and technological dimensions. The Smart City Index is constructed with an equal weight scheme, and the score is compared among smart cities and non-smart cities in South Korea. South

Korean smart cities can be categorized into two: first-wave and second-wave smart cities. First-wave smart cities are ubiquitous cities (u-cities). According to Korea Land and Housing Corporation who's in charge of national smart city development, 42 administrative cities implement U-city projects from 2009 to 2013. Second-wave smart cities are developed since 2014 when the government promoted using the term "smart city" instead of "U-city." Second-wave smart cities still emphasize ICT infrastructure, but they provide more smart services, including public administration, health and welfare, culture and tourism, and real-time facility management. The rest of the cities are non-smart cities. The Smart City Index for smart and non-smart cities are calculated in two years, 2008 and 2018.

The analysis showed that the second-wave smart cities scored highest while non-smart cities score the lowest. It means smart city development can result in desirable impacts compared to non-smart cities. The analysis also found there is an existing gap between smart and non-smart cities. To reduce this gap, it needs comprehensive smart city development plans. The policy also needs to consider the impacts of environmental and social dimensions. The difference in difference regression showed statistically significant results in two positive and three negative impacts. Two positive impacts are 1) an increase in satisfaction on income level (equality) and 2) an increase in the number of citizen initiatives (citizen involvement). Three negative impacts are 1) a decrease in employment of low-educated (citizen empowerment), 2) a decrease in the perception of transparency (transparency), and 3) a decrease in the perception of information security (privacy). Overall, this chapter provides initial empirical results on the impacts of smart city development.

Chapter 4 is the third paper, 'Smart energy transition: an evaluation of cities in South Korea.' This chapter provides empirical evidence of the smart city's effectiveness in environmental sustainability, especially the energy transition. Smart city and energy transition can be closely linked as they both seek comprehensive systematic change and aim for environmental sustainability. The advanced technologies used in smart cities can contribute to achieving the energy transition. This chapter presents a framework to link smart city and energy transition and develops a Smart Energy Transition Index to measure the performance. This chapter compares South Korean smart cities and non-smart cities. The city categories follow that of Chapter 3. Smart Energy Transition Index is constructed with seven indicators from three drivers of smart cities (technology, community, and policy) and their contributions to the energy transition. The Smart Energy Transition Index is calculated with an equal weight scheme. The hypothesis is smart cities will perform better than non-smart cities in the energy transition.

The descriptive result showed that second-wave smart cities scored highest in the Smart Energy Transition Index, followed by the first-wave smart cities and non-smart cities. Kruskal-Wallis test and Wilcoxon Rank-sum test are performed to find whether the descriptive results are statistically significant. The result showed that second-wave smart cities' mean is significantly different from that of first-wave smart cities and non-smart cities. There were exceptional cases that a non-smart city was included in the top 10 cities and two first-wave smart cities included in the bottom 10 cities. It implies the way smart city development is planned and executed can influence the results. The analysis considered the index with inherent urban smartness, including population, financial independence ratio, gross regional domestic production, and the urbanized area. The correlation test showed a positive relation between Smart Energy Transition Index and population, financial independence ratio, and urbanized area. It indicates the inherent urban smartness may influence smart energy transition.

Chapter 5 is the fourth paper, 'Dynamics in Governance of Smart Cities: Insights from South Korean Smart Cities.' Two previous empirical studies provide empirical evidence of smart cities in overall urban sustainability and energy transition. In this chapter, smart city development is studied through the lens of governance. In the literature, smart city development can positively influence governance by bringing all stakeholders in the decision-making process and providing a more transparent and democratic environment through ICT use. It is empirically studied with three smart cities in South Korea, analyzing how the governance model changes over the smart city development phases. A framework to identify the governance models was developed by looking into the actors, roles, and interaction modes. Four governance models (market, corporate, multilevel, and collaborative) are identified from the literature review. The data is collected from secondary data, National Smart City Master Plans, each city's smart city master plans, laws and regulations, news articles, reports from research institutes, and academic articles. The smart city development in South Korea is divided into three phases. The first phase is from 2008 to 2013, an initial phase to construct ICT infrastructures. The second phase is from 2014 to 2018, a maturing phase to provide smart city services and developing software for comprehensive smart urban management. The third phase is from 2019 to 2023, a conversions phase to establish an innovative platform that changes citizens' life.

The result showed Seoul, Songdo, and Sejong gradually changed to collaborative governance. In the first and second phases, Seoul's governance model was market, while Sejong was multi-level. Songdo changed from partnership PPP (collaborative) to market. In these phases, the governmental agencies were either facilitators or commissioners, while private actors were executers. Their interaction model was mostly participation. But in the third phase, the governance model changed to collaborative governance in all three cities. The government acknowledged the importance of citizen involvement and sought private and academic actors to be involved more. However, the governance model was distant from the theoretical definition of collaborative governance, a horizontal network, because the government still holds power in decision-making. We define this as a state-guided collaboration. South Korean planning culture is not used to participatory or collaborative planning. Strong leadership of the government planned and executed the urban development. This tradition is slowly changing, the government making more room for other non-governmental actors to be involved. The state-guided governance model can be useful for the countries and cities that are not used to participatory governance, or collaborative network is not formed autonomously. This chapter also proposes that market governance can be a practical choice in the initial phase even though smart cities pursue collaborative governance. The initial phase usually focuses on constructing and distributing ICT infrastructures, and market governance can accelerate the process. When the development phase matures, the governance model needs to evolve to collaborative governance, as in the end, citizens are influenced directly by the development. As smart city development proceeds, the governance model also matures.

Chapter 6, the conclusion, first summarizes the answers to the research questions. The answers are critically discussed concerning broader existing literature. The conclusion also provides the implication and future research agenda. Implications of this thesis are 1) it provides an overview of impacts of smart city development, whether it is positive or negative and hypothetical or observed; 2) it presents two evaluation tools, Smart City Index and Smart Energy Transition Index, and an evaluation framework for identifying the governance models; 3) this leads to providing empirical evidence on the performance of smart cities in overall urban sustainability; 4) it provides more explanation on environmental (energy transition) and governance impacts; 5) it suggests governance models suitable for the different development stages of smart cities. Future research can focus on in-depth empirical study for the impacts of smart city development and comparison among countries. Future research can also investigate citizens' views on smart city, and how governance influences the impacts of smart city development. Policy recommendations are 1) smart city development requires different approaches because cities have different capacities; 2) encouraging the participation of various stakeholders is important; 3) more attention is needed for citizens; 4) smart cities need national or even international level policies; 5) smart city development can be both opportunity and a crisis for developing countries. All in all, smart city development requires collaboration among public, private, academic, and civil initiatives to yield positive impacts (Yigitcanlar *et al.*, 2018).

Samenvatting

Smart cities (slimme steden) streven naar stedelijke duurzaamheid en hogere kwaliteit van leven door actief gebruik te maken van informatie- en communicatietechnologieën (ICT). Er is hoge ambitie naar smart cities en veel steden zijn al ondergedompeld in smart city ontwikkelingstrends. Onder andere Zuid-Korea is sinds het begin van de jaren 2000 begonnen met de ontwikkeling van smart cities als een van de nationale ontwikkelingsstrategieën. Meer dan 50 steden claimen 'slim' te zijn sinds de gemeenten smart city-projecten hebben geïnitieerd. Hiertoe rijzen enkele vragen. Wat zijn de effecten van smart city ontwikkeling? Wat zijn de empirische effecten van de ontwikkeling van smart cities op economisch, ecologisch, sociaal, bestuurlijk en technologisch vlak? Is er een verschil in prestatie tussen smart cities en non-smart cities?

Hoofdstuk 1 is de inleiding van dit proefschrift. Het legt de achtergrond en het doel van dit onderzoek uit. De achtergrond geeft het ontstaan en de evolutie van het smart city-concept weer. Daarna volgt de probleemstelling die de onderzoekskloof in kaart brengt. Er zijn veel studies over concepten, operaties en technologische ontwerpen van smart cities, maar er zijn weinig empirische studies over de effecten van de ontwikkeling van smart cities. Om deze onderzoekskloof op te vullen, wordt de belangrijkste onderzoeksvraag ontwikkeld: wat zijn de effecten van smart city ontwikkelingen op stedelijke duurzaamheid? Deze onderzoeksvraag is onderverdeeld in vier deelonderzoeken:

1) Hoe beschrijft de huidige literatuur de effecten van smart city ontwikkeling;
2) Wat zijn de algemene empirische effecten van smart city ontwikkeling op stedelijke duurzaamheid;
3) Wat zijn de empirische effecten van smart city ontwikkeling op milieuduurzaamheid, met name de energietransitie; en
4) Wat zijn de empirische effecten van smart city ontwikkeling op governance?

De laatste twee vragen besteden aandacht aan milieu- en bestuursaspecten van smart city ontwikkeling die minder aandacht hadden vanuit de academische wereld. Het smart city-concept wordt in detail geïntroduceerd, waarbij eerst een vergelijking wordt gemaakt met relevante

concepten als digitale stad (digital city), intelligente stad (intelligent city) en informatiestad (information city) en worden de definities en kenmerken van smart cities bestudeerd. In de rest van hoofdstuk 1 wordt ingegaan op de betekenis van het onderzoek en de samenstelling van het proefschrift.

Hoofdstuk 2 tot en met hoofdstuk 5 geven de vier artikelen weer die elk een antwoord geven op de deelonderzoeksvragen. Hoofdstuk 2 is het eerste artikel, getiteld 'Identificeren van de resultaten van smart city ontwikkeling: bevindingen uit systematisch literatuuronderzoek'. Dit artikel is gewijd aan het verzamelen van de effecten die verspreid zijn in de smart city-literatuur. Het maakt gebruik van een systematische literatuurstudie om kwalitatief te analyseren hoe de huidige literatuur de effecten van smart city ontwikkeling in beeld brengt. Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) protocol wordt gebruikt om de artikelen te identificeren en te analyseren. Als geschiktheidscriteria worden vakgebied, onderwerp, onderzoeksmethode, taal, publicatiestatus en database en publicatiejaar in aanmerking genomen. Artikelen worden verzameld uit Scopus en Web of Science. Op basis van de voorgeschreven criteria worden in totaal 55 artikelen geselecteerd voor analyse. Er worden twee standaarden gebruikt om de effecten te categoriseren: 1) positief of negatief; 2) hypothetisch of geobserveerd op basis van het empirische bewijs dat in elk artikel wordt voorgesteld.

Uit de analyse bleek dat er 12 positieve effecten en 4 negatieve effecten zijn die vaak genoemd worden in de artikelen. In de volgorde van frequentie zijn de geïdentificeerde positieve effecten: 1) het faciliteren van economische ontwikkeling; 2) het verhogen van de efficiëntie van openbare dienste; 3) het verbeteren van de betrokkenheid van de burgers; 4) het verhogen van kwaliteit van leven; 5) het beschermen van het milieu; 6) het faciliteren van sociale ontwikkeling; 7) het faciliteren van goed bestuur; 8) het empowerment van burgers; 9) het faciliteren van duurzame ontwikkeling; 10)het stimuleren van innovatie; 11)het versterken van samenwerking; 12)het vergroten van sociaal kapitaal. Van deze positieve effecten waren 3), 5), 6), 9), 10), 12) puur hypothetisch zonder empirisch bewijs. Er wordt relatief minder aandacht besteed aan negatieve effecten. De negatieve effecten zijn 1) het verzwaren/verbergen van stedelijke problemen; 2) polarisatie & ongelijkheid; 3) privacy- en veiligheidskwesties; 4) de afnemende vrijheid van meningsuiting en democratie. Van deze negatieve effecten waren 3) en 4) puur hypothetisch. Ook worden positieve effecten benadrukt in landen met een hoog inkomen, terwijl de negatieve effecten worden benadrukt in landen met een gemiddeld inkomen. Er waren geen casestudies van landen met een laag inkomen.

Hoofdstuk 3 is de tweede paper, getiteld 'Smart city impact index: het vinden van empirisch bewijs voor de effecten van smart city ontwikkeling'. Eerst worden indicatoren ontwikkeld voor de positieve en negatieve effecten die in hoofdstuk 2 zijn gevonden, waarvoor een herziening nodig is van de literatuur en de bestaande evaluatiemethoden. De effecten zijn gecategoriseerd in vier pijlers van duurzaamheid (economische, ecologische, sociale en bestuurlijke) en technologische dimensies. De Smart City Index is opgebouwd met een gelijke wegingsfactor schema, en de score wordt vergeleken tussen smart cities en non-smart cities in Zuid-Korea. Zuid-Koreaanse smart cities kunnen in twee categorieën worden onderverdeeld: eerste en tweede golf smart cities. Eerste golf smart cities zijn ubiquitous cities (u-cities). Volgens Korea Land and Housing Corporation, die verantwoordelijk is voor de nationale ontwikkeling van smart cities, voeren 42 administratieve steden tussen 2009 en 2013 U-city projecten uit. De tweede golf smart cities zijn ontwikkeld sinds 2014, toen de overheid de term "smart city" in plaats van "U-city" promootte. De tweede golf smart cities legt nog steeds de nadruk op ICT-infrastructuur, maar ze bieden meer slimme diensten aan, waaronder bij het openbaar bestuur, gezondheid en welzijn, cultuur en toerisme, en real-time faciliteitenbeheer. De rest van de steden zijn non-smart cities. De Smart City Index voor smart en non-smart cities wordt berekend in twee jaren, 2008 en 2018.

Uit de analyse bleek dat de tweede golf smart cities het hoogst scoorden, terwijl non-smart cities het laagst scoorden. Dit betekent dat smart city ontwikkeling kan leiden tot gewenste effecten in vergelijking met non-smart cities. Uit de analyse bleek ook dat er een kloof bestaat tussen smart en non-smart cities. Om deze kloof te verkleinen zijn uitgebreide plannen voor smart city ontwikkeling nodig. Het beleid moet ook rekening houden met de effecten van de milieu- en sociale dimensies. Het verschil in verschilregressie liet statistisch significante resultaten zien in twee positieve en drie negatieve effecten. Twee positieve effecten zijn 1) een toename van de tevredenheid over het inkomensniveau (gelijkheid) en 2) een toename van het aantal burgerinitiatieven (betrokkenheid van de burgers). Drie negatieve effecten zijn 1) afname van werkgelegenheid voor laagopgeleiden (empowerment van burgers), 2) een afname van de perceptie van transparantie (transparantie), en 3) een afname van de perceptie van informatiebeveiliging (privacy). Over het algemeen geeft dit hoofdstuk de eerste empirische resultaten van de effecten van smart city ontwikkeling.

Hoofdstuk 4 is de derde paper, getiteld 'Slimme energietransitie: een evaluatie van steden in Zuid-Korea'. Dit hoofdstuk geeft een empirisch bewijs van de effectiviteit van de smart city op het gebied van milieuduurzaamheid, met name de energietransitie. Smart city en energietransitie kunnen nauw met elkaar verbonden zijn, aangezien ze beide streven naar uitgebreide systematische verandering en streven naar milieuduurzaamheid. Vooral de geavanceerde technologieën die in smart cities worden gebruikt, kunnen bijdragen aan het realiseren van de energietransitie. Dit hoofdstuk biedt een kader om smart city en energietransitie met elkaar te verbinden en ontwikkelt een Smart Energy Transition Index om de prestaties te meten. In dit hoofdstuk worden de ervaringen van smart cities in Zuid-Korea opnieuw vergeleken met die in non-smart cities. De stadscategorieën volgen die van hoofdstuk 3. Smart Energy Transition Index is samengesteld met zeven indicatoren van drie drijvende krachten achter smart cities (technologie, gemeenschap en beleid) en hun bijdragen aan de energietransitie. De Smart Energy Transition Index wordt berekend met een gelijke wegingsfactoren schema. De hypothese is dat smart cities beter zullen presteren dan non-smart cities in de energietransitie.

Het resultaat liet zien dat de tweede golf smart cities het hoogst scoorde in de Smart Energy Transition Index, gevolgd door de eerste golf smart cities en de non-smart cities. De Kruskal-Wallis-test en de Wilcoxon Rank-sum-test worden uitgevoerd om te bepalen of de beschrijvende resultaten statistisch significant zijn. Het resultaat liet zien dat het gemiddelde van de tweede golf smart cities significant verschilt van dat van de eerste golf smart cities en de niet -smart cities. Er waren uitzonderlijke gevallen dat een non-smart city werd opgenomen in de top 10 steden en twee eerste golf smart cities in de onderste 10 steden. Dit impliceert dat de manier waarop smart cities worden gepland en uitgevoerd de resultaten kan beïnvloeden. De index wordt ook geanalyseerd met stedelijke kenmerken zoals bevolking, financiële onafhankelijkheidsratio, bruto regionale binnenlandse productie en het verstedelijkte gebied die inherent zijn aan stedelijke slimheid. De correlatietest toonde aan dat er een positieve relatie bestaat tussen de Smart Energy Transition Index en de bevolking, de financiële onafhankelijkheidsratio en het verstedelijkte gebied. Dit geeft aan dat de inherente slimheid van steden de slimme energietransitie kan beïnvloeden.

Hoofdstuk 5 is de vierde paper, getiteld 'Hoe smart cities zijn gemaakt: de governance van Koreaanse smart cities'. Twee eerdere empirische studies leveren empirisch bewijs van smart cities in de algehele stedelijke duurzaamheid en energietransitie. In dit hoofdstuk wordt smart city ontwikkeling bestudeerd vanuit het oogpunt van governance. In de literatuur kan smart city ontwikkeling een positieve invloed hebben op governance door alle belanghebbenden bij het besluitvormingsproces te betrekken en door het gebruik van ICT een transparantere en democratischere omgeving te bieden. Dit is empirisch onderzocht met drie smart cities in Zuid-Korea, waarbij werd geanalyseerd hoe het bestuursmodel verandert in de fasen van smart city ontwikkeling. Er werd een kader ontwikkeld om de bestuursmodellen te identificeren door te kijken naar de actoren, hun rollen en interactiemodus. Uit de literatuurstudie zijn vier bestuursmodellen (markt, corporate, multilevel en collaboratief) geïdentificeerd. De gegevens worden verzameld uit secundaire gegevens, National Smart City Master Plans, de smart city masterplannen van elke stad, wet- en regelgeving en nieuwsartikelen, rapporten van onderzoeksinstituten en academische artikelen. De ontwikkeling van smart cities in Zuid-Korea is onderverdeeld in drie fasen. De eerste fase loopt van 2008 tot 2013, een eerste fase voor de aanleg van ICT-infrastructuren. De tweede fase is van 2014 tot 2018, een rijpende fase voor het leveren van smart city diensten en het ontwikkelen van software voor omvangrijke smart urban management. De derde fase is van 2019 tot 2023, een conversiefase om een innovatief platform op te zetten dat het leven van de burgers verandert.

Het resultaat liet zien dat Seoel, Songdo en Sejong geleidelijk aan zijn veranderd in een gezamenlijk bestuur. In de eerste en tweede fase was Seoels bestuursmodel marktgericht, terwijl Sejong multi-level was. Songdo veranderde van partnership PPP (collaborative) naar markt. In deze fasen waren de overheidsinstanties ofwel facilitatoren of commissarissen, terwijl private actoren uitvoerders waren. Hun interactiemodus was voornamelijk participatie. Maar in de derde fase veranderde het bestuursmodel in gezamenlijk bestuur in alle drie de steden. De overheid erkende het belang van burgerbetrokkenheid en streefde naar meer betrokkenheid van private en academische actoren. Het governancemodel stond echter ver af van de theoretische definitie van collaboratief bestuur, dat een horizontaal netwerk is, omdat de overheid nog steeds de macht heeft bij de besluitvorming. Dit wordt gedefinieerd als een door de staat geleide samenwerking. De Zuid-Koreaanse planningscultuur is niet gewend aan participatieve of collaboratieve planning. Sterk leiderschap van de overheid plande en voerde eerder de stedelijke ontwikkeling uit. Deze traditie verandert langzaam, waarbij de overheid meer ruimte maakt voor andere niet-gouvernementele actoren. Het staatsgeleide bestuursmodel kan nuttig zijn voor de landen en steden die niet gewend zijn aan participatief bestuur of samenwerkingsverbanden dat niet autonoom is gevormd. Ook wordt in dit hoofdstuk voorgesteld dat marktgovernance in de beginfase een effectieve keuze kan zijn, ook al streven smart cities naar collaboratief bestuur. De beginfase richt zich meestal op de aanleg en distributie van ICT-infrastructuren en marktgovernance kan het proces versnellen. Wanneer de ontwikkelingsfase volwassen wordt, moet het governancemodel evolueren naar collaboratieve governance, aangezien de burgers uiteindelijk rechtstreeks door de ontwikkeling worden beïnvloed. Naarmate de ontwikkeling van smart cities volwassen wordt, rijpt ook het bestuursmodel.

Hoofdstuk 6, de conclusie, vat eerst de antwoorden op de onderzoeksvragen samen. De antwoorden worden kritisch besproken aan de hand van bredere bestaande literatuur. De conclusie geeft ook de implicatie en de toekomstige onderzoeksagenda weer. Implicaties van dit proefschrift zijn 1) het geeft een overzicht van de effecten van smart city ontwikkeling, of deze nu positief of negatief is en hypothetisch of geobserveerd; 2) het presenteert twee evaluatie-instrumenten, Smart City Index en Smart Energy Transition Index, en een evaluatiekader voor het identificeren van de bestuursmodellen; 3) dit leidt tot het leveren van empirisch bewijs over de prestaties van smart cities op het gebied van algehele stedelijke duurzaamheid; 4) het geeft meer uitleg over de effecten op het milieu (energietransitie) en op governance; en 5) het stelt bestuursmodellen voor die geschikt zijn voor de verschillende ontwikkelingsfasen van smart cities. Toekomstig onderzoek kan zich richten op een diepgaande empirische studie naar de effecten van de ontwikkeling van smart cities en vergelijking tussen landen. Toekomstig onderzoek kan ook de visie van de burgers op smart cities onderzoeken, en hoe het bestuur de effecten van smart city ontwikkeling beïnvloedt. Beleidsaanbevelingen zijn: 1) smart city ontwikkeling vereist verschillende benaderingen omdat steden verschillende capaciteiten hebben; 2) het stimuleren van de deelname van verschillende belanghebbenden is belangrijk; 3) er is meer aandacht nodig voor de burgers; 4) smart cities hebben beleid op nationaal of zelfs internationaal niveau nodig; en 5) smart city ontwikkeling kan zowel een kans als een crisis zijn voor ontwikkelingslanden. Al met al vereist smart city ontwikkeling samenwerking tussen publieke, private, academische en civiele initiatieven om positieve effecten te hebben (Yigitcanlar et al., 2018).

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Chapter 1

Introduction

Han River, Seoul, South Korea, Yirang Lim

1 Introduction

This thesis intends to explain how smart city development influences the sustainability of the cities. It touches upon the impacts of smart cities theoretically and empirically. It presents the South Korean experience, where the national government strongly promotes smart city development. It provides an overview of smart city development's positive and negative impacts, whether hypothesized or observed by a systematic literature review. An evaluation index is developed considering economic, environmental, social, governance, and technological dimensions. The result showed more attention is needed to the environmental and governance impacts of smart city development. Hence, this thesis goes deeper into the environmental and governance impacts of smart city development. Since smart cities aim to reduce CO_2 emission and energy use, they can contribute to the energy transition to a low-carbon society. To this end, an evaluation index is developed to measure the smart cities' contribution to the energy transition. As for the governance impact, this thesis identifies governance models from different stages of the development process. The introduction consists of six sub-sections. It first narrates the background of smart city literature, and then the problem statement defines the research gap. The third sub-section introduces the main research question and four sub-research questions. The fourth sub-section introduces the smart city concept. Then the significance of this research is provided, followed by the structure of the thesis.

1.1 Background

The information revolution in the 1990s changed the way people live. The diffusion of cellphones, personal computers, and internet networks changed how people interact, work, and play. It also influenced urban development and management. Advanced technologies used in the military and aerospace are used in civil engineering and industry to meet the growing demand for urban infrastructure (Hall et al., 2000). These intelligent and adaptive materials are implemented in urban infrastructure, developing innovative solutions for urban problems. Using technology in urban planning became a popular topic (Albino, Berardi, and Dangelico, 2015).

Information and Communication Technology (ICT) infrastructures such as sensors, wireless internet networks, and Internet of Things (IoT) enabled the gathering and processing of massive amounts of real-time data to manage cities better. Utilizing ICT in urban systems has many names, such as digital city, intelligent city, knowledge city, or ubiquitous city (Hall et al., 2000; Cocchia, 2014). These concepts lead to the smart city concept, which was concretized in the late 2000s as new urban planning methods to tackle “wicked problems” (Afzalan, Sanchez & Evans-Cowley, 2017). The term ‘smart city’ became fashionable after IBM’s ‘smarter planet’ project in 2008. IBM seeks to implement ICT in everyday urban life, including banking, shopping, education, energy, food, health, and public services (Wiig, 2015). Soon after, frontier cities such as Vienna, Aarhus, Amsterdam, Cairo, Lyon, Malaga, and Songdo started smart city projects. The idea of smart city became attractive to governments and businesses. For governments, smart cities can reduce the administrative burden, increase efficiency in urban management, and attract skilled and educated people to rehabilitate urban competitiveness and growth (Harrison & Donnelly, 2011). For businesses, smart cities can be a new market to test their innovative services.

More recently, the smart city’s notion became a comprehensive urban development and management method that utilizes high-tech appliances (Paroutis, Bennett & Heracleous, 2014). Several systematic literature reviews have been conducted to conceptualize smart city by comparing it with other concepts. Cocchia (2014) compared the concept of smart city and digital city from 1993 to 2012 and identified similarities and differences between those two concepts. Over time, the definition of smart city embraced the definition of digital city. The review acknowledged that smart or digital cities are derived from the empirical implementation of technology. Trindade et al. (2017) analyzed the smart city concept in association with sustainable development. They argued, "the smart city concept is viewed as a vision, manifesto or promise aiming to constitute the twenty-first century's sustainable and ideal city form (p.11)." This research helps understand how the smart city concept has emerged and developed, how it is different from other similar concepts such as digital city and sustainable city, and how smart city principles are applied in various sectors within cities.

Although there is no universally agreed definition, a commonly recognized feature of a smart city is the use of advanced technologies (Gil-Garcia, Pardo & Nam, 2015; Angelidou, 2017b). Implementing ICT in urban systems can provide efficient and effective service delivery, thus increasing prosperity and the quality of citizens' life. However, current smart city development has been criticized because it is biased toward technological implementation and corporate-driven urban planning, putting less attention on the role of people and the community (Hollands, 2008; Kitchin, 2015). This tendency raises concerns such as the digital divide, privacy issues, and the gap between the haves and have-nots. Human, social, and relational capital are essential components to mitigate these side-effects. Thus, ICT and smart people are vital to becoming a smart city (Shapiro, 2006; Hollands, 2008; Kitchin, 2015). The existence of educated and skillful people fosters innovations while advanced technologies serve as an enabler or supporter of facilitating those innovations.

1.2 Problem Statement

Smart city literature can be broadly categorized into two streams: engineering and computer science literature focusing on the technologies (e.g., Jin *et al.*, 2014; Perera *et al.*, 2014; Zanella *et al.*, 2014; Hashem *et al.*, 2016), and social science and urban planning literature focusing on the theory of a smart city (e.g., Hollands, 2008; Caragliu, Del Bo & Nijkamp, 2009; Batty, 2013; Neirotti *et al.*, 2014; Albino et al., 2015). The former body of the literature concerns the development of technologies, systems, and platforms that can be implemented in smart cities. On the other hand, the latter conceptualizes a smart city and analyzes its operation by defining what is smart and identifying the dimensions or frameworks of the smart city. This thesis is in line with the latter stream, focusing on the impacts of smart city development on urban sustainability.

The studies on smart city concepts mainly focus on smart cities' concepts and characteristics (for example, Zygiaris, 2013; Cocchia, 2014; Arafah & Winarso, 2017; Mora, Bolici & Deakin, 2017; Trindade *et al.*, 2017). Some more specific topics include the economy, culture, politics, and smart cities' governance (Kim, Jung & Choi, 2016; Rossi, 2016; Das, 2017; Ruhlandt, 2018). Simultaneously, some researches concern the negative impacts of technology-driven urban development (Hollands, 2008; Galdon-Clavell, 2013; Datta, 2015b). These studies are meaningful in that they provide insights on the sectoral positive and negative impacts of smart cities. However, the overall impacts of smart city developments on urban sustainability have not been systematically recorded. Here, urban sustainability means ensuring citizens' quality of life in environmental, social, governance, and economic dimensions (Yigitcanlar & Teriman, 2015). It is in line with smart city literature, where smart cities are believed to facilitate sustainable development in the economy, environment, society, and governance (Wiig, 2015; Yigitcanlar, 2015; Gil-Garcia, Zhang & Puron-Cid, 2016).

In theory, smart cities are view as transformation process to "sustainable urban futures" by using technologies (Mora *et al.*, 2020). Compared to the literature on smart cities' conceptualization, a limited number of empirical studies analyze and evaluate smart cities' operations (Lim, Edelenbos & Gianoli, 2019a). It is because smart city development is a relatively new approach in planning. Also, smart cities' implementations are limited to several sectors in urban systems, such as transportation, e-government, or safety and security, not as a holistic urban planning model. However, smart city projects have been implemented since the 1990s, such as Adelaide and Seoul (Allwinkle & Cruickshank, 2011), eligible for the analysis.

In particular, the South Korean government invested in constructing ICT infrastructures, digitalizing public administration, and establishing a smart city platform since the early 2000s. Now more than 50 municipalities initiated smart city projects. South Korean experience is an interesting case with the central government's strong leadership, pulling the project from the initiation to completion. Analyzing the twenty years of practice can provide insights to understand the impacts of smart city development on urban sustainability.

Also, smart city research mostly focuses on economic development and efficiency driven by ICT, and there is little attention to environmental aspects (De Jong *et al.*, 2015). 'Green environment' is mentioned in some of the definitions (see section 1.4.2 for definitions), but it lacks a clear definition. Since smart cities aim to optimize resource use that can lead to less energy consumption (Neirotti *et al.*, 2014), smart cities have the potential for environmental sustainability. Specifically, energy transition, a systematic change to a low-carbon society (Bridge *et al.*, 2013), can benefit from advanced technologies and smart cities' human and social capitals. Smart technologies, backed up by appropriate policies and measures, are essential in smart energy transition (Van Leeuwen, De Wit & Smit, 2017). Since the energy transition requires a shared vision of field actors (Frickel *et al.*, 2016), a smart city can be the shared vision. Some studies in the energy transition also acknowledged the integrated smart energy system as part of smart city development that facilitates renewable energy, efficiency, and sustainability (Orecchini & Santiangeli, 2011; Lund *et al.*, 2012; Mathiesen *et al.*, 2015; Leem, Han & Lee, 2019). These studies provide innovative system designs for the energy sector. However, we still do not fully understand smart cities' contribution to the energy transition.

Along with little attention to the environmental sustainability of smart city development, there is also less attention to the governance dimension of smart city development (De Jong *et al.*, 2015; Meijer & Bolívar, 2016). Smart city governance has two different views. One is seeing smart governance (collaborative governance, citizen engagement, participatory and democratic governance) as a result of smart city development (e.g., Kitchin, 2014), and the other is considering participatory governance as one of the drivers of smart cities (Caragliu et al., 2009). In this research, smart governance is regarded as one of the impacts of smart city development. This research pays attention to South Korea's experience in developing smart cities and how the governance model changes during the development process. Theoretically, smart city governance emphasizes network, partnership, and collaboration among actors and community engagement (Toppeta, 2010; Gil-Garcia et al., 2015). Major actors in smart city governance are the government (public agency), corporates, and citizens (Lombardi, Giordano, Caragliu, *et al.*, 2012; Deakin, 2014), as well as research institutes (Fernandez-Anez, Fernández-Güell & Giffinger, 2018). The relationship among these actors defines the governance model.

Smart city projects cost a lot, not only financial input but also technological, human, and institutional capital. And they can divert policy priority from more important issues such as housing deficit, unemployment, or poverty (Barns et al., 2017). Recognizing these characteristics of the current smart city agenda, knowing the impacts of smart cities has become an important issue. There are high expectations and promises, but real evidence is seldom presented. What are the results of smart city development? Are they positive or negative? Are those impacts already observed in reality? How do we measure positive and negative impacts? What about environmental sustainability? Is smart city development beneficial to the energy transition? How the governance model changes according to smart city development? These questions are important to reflect on the current smart city development path and to shape future directions. This thesis dedicates to answer these questions to provide evidence-based knowledge that contributes to understanding how smart city development influence urban sustainability.

1.3 Research Questions

This thesis aims to identify the impacts of smart city development and find to what extent the impacts are realized in smart cities. This research mainly focuses on the South Korean experience for some reasons. First, the author has a South Korean background, making it convenient to access data and resources in South Korea. Second, South Korea, especially Seoul, can be considered the front runner of smart city development. South Korean government promotes smart city development as one of the national development strategies, and this systematic promotion offers various cases to examine the impacts of smart city development. The main research question is, "What are the impacts of smart city development on urban sustainability?" It can be further specified into four research questions:

RQ1. How does the current smart city literature portray the impacts of smart city development?

- How do the selected articles conceptualize smart cities?
- What are the impacts of smart city development? Are they positive or negative? Are they hypothetical or observed?

RQ2. What are the overall empirical impacts of smart city development on urban sustainability?

- What indicators measure the positive and negative impacts in economic, environmental, social, governance, and technological dimensions?
- What are the observed impacts? Are they statistically significant?

RQ3. What are the empirical impacts of smart city development on environmental sustainability, especially the energy transition?

- What is the relationship between environmental sustainability, energy transition, and smart city development?
- Are smart cities better than non-smart cities in the performance of the energy transition?

RQ4. What are the empirical impacts of smart city development on governance?

- How do we identify the governance model empirically?
- How does the governance model change in different phases of smart city development?
- What is the appropriate governance model for developing smart cities?

This thesis is based on the paper publication, which comprises four academic papers. Each paper is designed to answer the four research questions. Table 1.1 summarizes each paper's research method and publication status.

Table 1.1 Overview of Thesis

Chapter	Research Question	Method	Publication Status
1. Introduction	-	-	-
2. Identifying the Result of Smart City Development: Findings from a Systematic Literature Review	RQ1	Qualitative method	Published in Cities (Elsevier) on 9th July 2019. https://doi.org/10.1016 /j.cities.2019.102397
3. What is Impact of Smart City Development? Empirical Evidence from Smart City Impact Index	RQ2	Quantitative method	Under review in the Journal of Urban Technology (Tailor and Francis). Submitted on 21st May 2020.
4. Smart Energy Transition: An Evaluation of Cities in South Korea	RQ3	Quantitative method	Published in Informatics (MDPI) on 6th November 2019. https://doi.org/10.3390 /informatics6040050

5. Dynamics in Governance of Smart Cities: Insights from South Korean Smart Cities	RQ4	Qualitative method on three case studies	Under review in the Government Information Quarterly (Elsevier). Submitted on 24th July 2020.
6. Conclusion	-	-	Parts of conclusion submitted in a book: Fransen, J., M.P. van Dijk and J. Edelenbos (eds.), New Paradigms in Urban Management, published by Edward Elgar Publishing, date of publication Spring 2021.

1.4 Smart City Concept

1.4.1 Smart City and Relevant Concepts

This section provides more details about the smart city concept. As mentioned in the previous section, there are various ways to name the trend utilizing ICT in urban planning: digital city, intelligent city, information city, intelligent city, knowledge city, ubiquitous city, and smart city (Albino et al., 2015; Cocchia, 2014; Gil-Garcia et al., 2015; Nam & Pardo, 2011a). These city categories are closely linked together, derived from the sustainable city concept (De Jong et al., 2015). Table 1.2 summarizes the definitions of each concept. Digital city is a frequently reoccurring concept related to smart city (Cocchia, 2014). It is a city where network and open access to information is emphasized (Anthopoulos & Fitsilis, 2010). A Digital city is based on a physical city, collecting and processing urban information and providing it to citizens and visitors (Harrison & Donnelly, 2011). It emphasizes the network among the public, private organizations, NGOs, communities, and citizens (Mechant et al., 2012).

Table 1.2 Definitions of Concepts

Concept	Definition	Source
Digital city	"The concept of digital cities is to build an arena in which people in regional communities can interact and share knowledge, experiences, and mutual interests. Digital cities integrate urban information (both achievable and real time) and create public spaces in the Internet for people living/visiting the cities"	Ishida (2002), p.76
	"The digital city is as a comprehensive, web-based representation, or reproduction, of several aspects	Couclelis (2004), pp.5-6.

	or functions of a specific real city, open to non-experts." […] "Digital cities are `place based'" […] and "they are meant to be accessible to the public in the broad sense rather than to any particular groups of experts, professionals, special interests, or urban managers"	
	"Networks of organizations, social groups and enterprises located in a city area are called digital cities. The evolution to municipal ICT environments -based on metropolitan networks such as metro-Wi-Fi- composed a recent digital city definition: city-area infrastructures and applications aiming to cover local needs and support local community's everyday life"	Anthopoulos & Fitsilis (2010), p.301
Ubiquitous city	"A city or region with ubiquitous information technology. All information systems are linked, and virtually everything is linked to an information system through technologies such as wireless networking and RFID tags"	Anthopoulos & Fitsilis (2009), p.361
Intelligent city	"Intelligent cities and regions are territories with high capability for learning and innovation, which is built-in the creativity of their population, their institutions of knowledge creation, and their digital infrastructure for communication and knowledge management"	Komninos (2006), p.53
	"The label intelligent implies the ability to support learning, technological development, and innovation in cities"	Albino, et al. (2015), p.8
Knowledge city	"A Knowledge City is a city that aims at a knowledge-based development, by encouraging the continuous creation, sharing, evaluation, renewal and update of knowledge. This can be achieved through the continuous interaction between its citizens themselves and at the same time between them and other cities' citizens. The citizens' knowledge-sharing culture as well as the city's appropriate design, IT networks and infrastructures support these interactions"	Ergazakis, et al. (2004), p.7
Information city	"digital environments collecting official and unofficial information from local communities and delivering it to the public via web portals are called information cities"	Anthopoulos & Fitsilis (2010), p.301

The ubiquitous city is a realized digital city on the urban territory (Mechant et al., 2012). In the ubiquitous city, citizens can access public services or information anytime, anywhere in the city using ubiquitous computing technology (Anthopoulos & Fitsilis, 2010). The South Korean government mainly promoted it in the late 2000s. An intelligent city aims to enhance citizens' quality of life by facilitating information distribution using ICT (Mechant et al., 2012). It is similar to the digital city and smart city that it widely applies to digital and electronic devices within a city (Vicini, Bellini, & Sanna, 2012). An intelligent city is a formula of human capacity, ICT infrastructure, and information (Malek, 2009). Although it is hard to differentiate between intelligent cities and smart cities, intelligent cities tend to focus on innovation by using the technologies rather than applying the technologies so that it is limited to promote services (Allwinkle & Cruickshank, 2011). Intelligent city and knowledge city are similar in that the two concepts emphasize creativity, human capital, and learning. Universities and research institutes play an important role in knowledge city. Information city emphasizes collecting and distributing this information to the public (Anthopoulos & Fitsilis, 2010). In that sense, it is nearly the same as the digital city. The difference is digital city emphasizes the role of digital application in urban areas while the information city concentrates on the use of information.

Several differences among the concepts are detected. First, knowledge city is the most different concept from the others, emphasizing knowledge creation and the role of universities and research institutes. The other concepts concern innovative urban management and development strategies, while knowledge city concerns learning and making value out of it. In a knowledge city, technology supports knowledge sharing and interaction. Second, Digital city, ubiquitous city, and intelligent city concerns with public service provision. Holland (2008) remarks that a smart city is an advanced version of a knowledge city, as the smart city adds social and human capital to ICT. The smart city encompasses broader topics such as innovation, smart technologies, and smart governance, while the digital city mainly focuses on web-services (De Jong *et al.*, 2015). All the concepts mentioned above focus on specific aspects of the smart city in general (Albino et al., 2015).

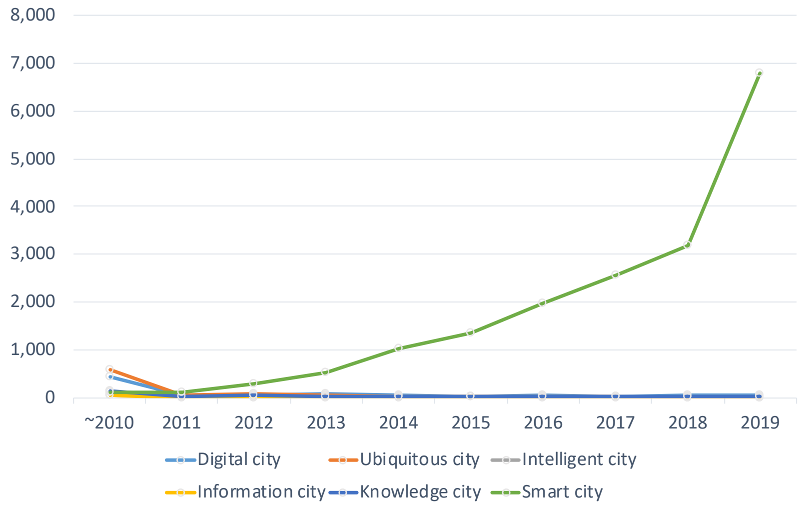

Figure 1.1 Search Result of City Categories in Google Scholar
Source: google scholar (search conducted 19-08-2020)

A brief search on Google Scholar explains how different terms to describe technology-driven urban planning have changed. Six keywords were searched: smart city, intelligent city, information city, digital city, ubiquitous city, and knowledge city and their plural form (cities). Each exact term should be included in the title. The search results of the ubiquitous city and knowledge city also account for u-city and knowledge-based city, respectively. As Figure 1.1 shows, before 2010, ubiquitous city and digital city were the dominant terms. However, from 2012, smart city became the most frequently used term. It even became more famous than sustainable city by 2012 (De Jong *et al.*, 2015). The next section reviews the definitions of the smart city in the literature in more detail.

1.4.2 Definitions and Characteristics of Smart Cities

Gil-Garcia et al. (2015) analyzed that the smart city phenomenon is a "socio-technical phenomenon." They pointed out that previous literature's definitions have five commonalities: 1) emphasis on ICT, 2) the importance of critical infrastructures, mainly physical and network infrastructures, 3) better service provision, 4) interconnection of systems and infrastructures, and 5) vision for better future. They also identified critical components of a smart city: the physical environment, society, and government, which all are influenced by technology and data. This research is in line with their argument. ICT indeed provides a new corridor for efficient urban management and development.

Table 1.3 shows the definitions and characteristics of smart cities from previous studies. The majority of definitions state the purpose of a smart city is to enhance the quality of life and economic prosperity. To achieve this purpose, the common feature of the smart city is the extensive use of ICT. The smart city's expected impacts include efficient resource use, effective public service delivery, making safe and environmentally friendly living conditions.

The definitions of smart cities emphasize implementing ICT in urban systems (Hall et al., 2000; Dirks & Keeling, 2009; Harrison & Donnelly, 2011). The belief is that smart cities can provide improved living conditions with better economic performance, environment-friendly built environment, and more efficient public services. ICT infused urban systems enable gathering, processing, and sharing real-time data on citizens' activities. Based on the massive amount of data, public organizations or private businesses can develop better goods and services. Smart cities also acknowledge the importance of human, social, and institutional capital that enables innovative strategies, policies, and programs to achieve urban sustainability (Caragliu et al., 2009; Giffinger et al., 2007; Zygiaris, 2013).

Table 1.3 Definitions and Characteristics of Smart City

Key Words	Definition or Characteristics of Smart City	Source
ICT, information, efficiency, environment, green	"The vision of 'Smart Cities' is the urban center of the future, made safe, secure environmentally green, and efficient because all structures – whether for power, water, transportation, etc. are designed, constructed, and maintained making use of advanced, integrated materials, sensors, electronics, and networks which are interfaced with computerized systems comprised of databases, tracking, and decision-making algorithms."	Hall (2000), p.1
Connection, ICT, intelligence	A Smarter city is "connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city."	Harrison et al. (2010), p.2
Human capital	"A Smart City is a city well performing in a forward-looking way […] built on the 'smart' combination of endowments and activities of self-decisive, independent and aware citizens."	Giffinger (2007), p.11

ICT (smart computing), efficiency	"What makes a city a smart city is its use of Smart Computing to deliver its core services (city administration, education healthcare, public safety, real estate, transportation, and utilities) to the public in a remarkably efficient manner"	Washburn et al. (2009), p.2
Technology, resource optimization	"A smarter city is one that uses technology to transform its core systems and optimize the return from largely finite resources"	Dirks & Keeling (2009), p.9
ICT, freedom, accessibility	"The "Smart City" refers to a city where the ICT strengthen the freedom of speech and the accessibility to public information and to public services."	Anthopoulos & Fitsilis (2010), p.302
ICT, efficiency, sustainability, livability	"Smart cities are those that are combining ICT and Web 2.0 technology with other organizational, design and planning efforts to de-materialize and speed up bureaucratic processes and help to identify new, innovative solutions to city management complexity, in order to improve sustainability and 'livability'"	Toppeta (2010), p.4
Human and social capital, ICT, sustainable development, quality of life, participatory governance	"We believe a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance."	Caragliu, et al. (2009), p.70
Technology, improvement	"A city that is planned, developed, and operated based on any form of technology" "Pragmatic, engineering-based attempt to improve the operation of individual urban infrastructure and services"	Harrison & Donnelly (2011), p.4
Innovation, sustainable development	"Cities prioritize their urban innovation ecosystems from their traditional urban character to innovative 'green', 'smart', 'open', 'intelligent', and 'innovating', aiming towards environmental and social sustainability."	Zygiaris (2013), p.218
ICT, resource optimization	"SCs are characterized by a pervasive use of Information and Communication Technologies (ICT), which, in various urban domains, help cities make better use of their resources."	Neirotti, et al. (2014), p.25

ICT, citizen participation, knowledge, innovation, human capital	"On the one hand, the notion of a 'smart city' refers to the increasing extent to which urban places are composed of […] pervasive and ubiquitous computing and digitally instrumented devices built into the very fabric of urban environments […] that are used to monitor, manage and regulate city flows and processes, often in real-time, and mobile computing […] used by many urban citizens to engage with and navigate the city which themselves produce data about their users […] On the other hand, the notion of a 'smart city' is seen to refer more broadly to the development of a knowledge economy within a city-region. From this perspective, a smart city is one whose economy and governance is being driven by innovation, creativity and entrepreneurship, enacted by smart people."	Kitchin (2014), p.1-2
Improvement, resource optimization	Although there is not yet a formal and widely accepted definition of "Smart City," the final aim is to make a better use of the public resources, increasing the quality of the services offered to the citizens, while reducing the operational costs of the public administrations.	Zanella, et al. (2014), p.22

1.5 Significance of the Study

This research gives valuable insights to the cities and governments who wish to start or expand smart city development. First, it provides a map of the positive and negative impacts of smart city development. Many works of literature focus on the positive side of smart city development while just a handful of studies argue about the negative impacts (some works including Datta, 2015b; Watson, 2015). Through a systematic literature review, this research tried to map the positive and negative impacts. The kinds and characteristics of impacts are also analyzed, showing how impacts are presented in the current literature. Impacts are also analyzed by field of study and country of case studies.

Second, it provides an evaluation framework for current smart city development, both considering positive and negative impacts. The existing frameworks do not distinguish the pre-requisites of a smart city and the outcomes from those pre-requisites (e.g., Hara *et al.*, 2016; Shen *et al.*, 2018). In other words, necessary components to become a smart city are not distinguished from the outcomes by utilizing those components. Pre-requisites such as ICT infrastructure need to be differentiated from a smart city's performance, such as enhanced public administration. This research provides a new framework to evaluate both positive and negative impacts. It focuses on the results or outcomes of smart city development rather than components of smart cities. The framework can assist in evaluating smart city's development progress.

Third, using the framework, this research provides empirical evidence of smart city impacts. Smart city concepts and technologies are widely studied, but few empirical studies on smart cities' impact. Also, current literature mainly focuses on positive impacts. This research tried to find evidence of both positive and negative impacts by studying the South Korean experience.

Fourth, it places special attention to environmental sustainability, energy transition in particular. Environmental sustainability calls more attention due to rapid climate change, and it requires systematic change. Smart cities are equipped with advanced technologies and innovative ideas that can assist in the smart energy transition. This research presents a framework for smart cities' potential support to the energy transition with three drivers, technology, community, and policy.

Fifth, this research compares smart and non-smart cities empirically. There have been studies to identify smart cities by measuring their capacity and performance, but less attention was given to comparing smart and non-smart cities. Smart cities are criticized for their 'self-congratulatory' manner (Hollands, 2008). The research formulates a hypothesis that even these self-declared smart cities are better performing than non-smart cities. And it found statistical evidence to back up the hypothesis. Smart cities perform better in economic and social dimensions as well as in smart energy transition.

And finally, it provides a framework to recommend the governance model by development phases. Theoretically, smart city governance pursues collaborative governance that emphasizes network, partnership, and collaboration (Gil-Garcia et al., 2015), as well as community engagement (Toppeta, 2010). However, the process of making smart cities can take different governance models. In the initial phase when the ICT infrastructures are built, strong leadership of the government can be efficient. When the smart city development matures, it is desirable to switch to collaborative governance where all the actors are involved. Table 1.4 summarizes each article's theoretical and main contributions.

Table 1.4 Contribution of Articles

Article	Theoretical Contribution	Main Contribution
Identifying the Result of Smart City Development: Findings from a Systematic Literature Review	• Analyzing smart city definitions by component, performance, and goals to reveal the concepts already include positive impacts such as sustainable development and high quality of life • Synthesizing scattered researches on positive and negative impacts of smart city development	• There are 12 positive and four negative impacts of smart city development identified. • Smart city literature emphasizes hypothetical positive impacts • There is less attention to negative impacts • More empirical studies are needed as six positive impacts and two negative impacts are purely hypothetical • Smart city researches are active in high-income countries, focusing on positive impacts. Middle-income countries are more concern about the negative impacts of smart city development while low-income countries are not included in the smart city research scope yet
What is Impact of Smart City Development? Empirical Evidence from Smart City Impact Index	• Categorizing smart city impacts into four pillars of sustainable development and technological dimensions • Providing concrete definitions of impacts and identifying indicators and variables to measure each impact	• Smart City Impact Index is constructed to compare the performance of smart and non-smart cities in sustainable development • In average, the Smart City Impact Index score became higher than non-smart cities in economic, environmental, social, governance, and technological dimensions from 2008 to 2018 • The pre-existing gap between smart and non-smart cities may influence the change (e.g., economic assets, better perception of transparency and democracy) • There is statistically significant evidence of both positive and negative impacts of smart city development

Smart Energy Transition: An Evaluation of Cities in South Korea	• Linking the energy transition and smart city development • Identifying indicators and variables to measure smart cities' contribution to the energy transition	• Three drivers of smart city (technology, community, and policy) can contribute to the energy transition • Smart Energy Transition Index score is high in smart cities than in non-smart cities on average • Smart Energy Transition Index correlates with population, financial independence ratio, and the urbanized area, which are inherent urban smartness
Dynamics in Governance of Smart Cities: Insights from South Korean Smart Cities	• Clarifying characteristics of smart governance • Defining actors' roles and interaction modes in four governance models	• Smart city researches on the governance dimension emphasize collaborative/participatory governance, community engagement, and use of ICT • Although collaborative governance is a desirable model in smart cities, there can be a different governance model in the development process • Initial phases of smart city development, in particular, strong leadership of the public sector (e.g., corporate governance), can be efficient when participatory planning is not a culture

1.6 Composition of the Thesis

Figure 1.2 shows the synopsis of this research. This research focuses on finding the impacts of smart city development on urban sustainability. The first article (Chapter 2) is about theoretical positive and negative impacts identified by a systematic literature review. The rest of the articles are empirical studies. The second article (Chapter 3) focuses on developing a comprehensive index that measures both positive and negative impacts of smart city development on economic, social, environmental, and governance sustainability.

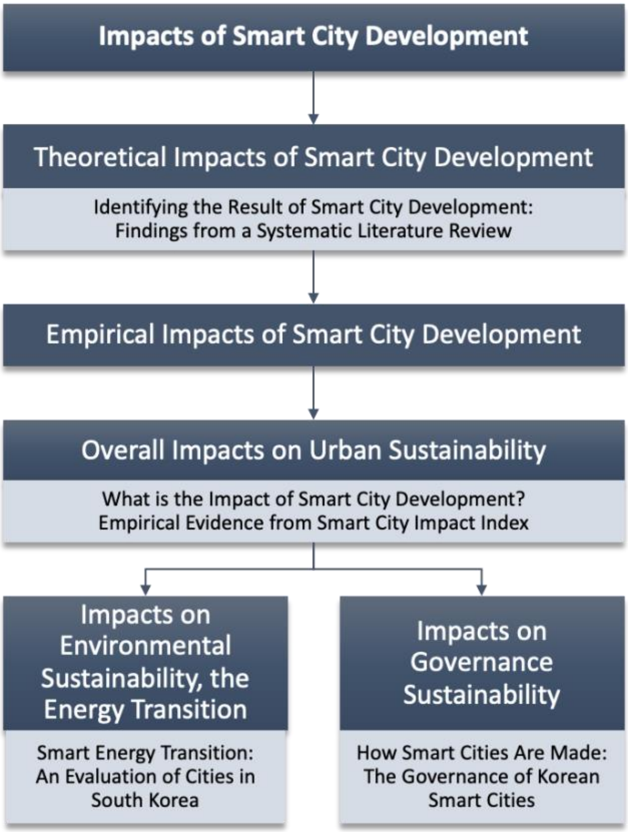

Figure 1.2 Synopsis of the Thesis

The third and fourth articles (Chapter 4 and 5) go more in-depth on specific dimensions of sustainability: environment and governance. The third article puts attention on environmental sustainability, the energy transition in particular. It provides a Smart Energy Transition Index. Since smart cities emphasize optimal use of resources, reducing CO_2 emission, and energy consumption, they share a framework with energy transition. This research tried to reveal the empirical impacts of smart cities on environmental sustainability by finding their contribution to the energy transition. The final article is about governance in smart cities. It identifies governance models in different smart city development stages and suggests appropriate governance models for development processes.

Chapter 2

Identifying the Results of Smart City Development: Findings from Systematic Literature Review

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2 Identifying the Results of Smart City Development: Findings from Systematic Literature Review

2.1 Abstract

Smart city is an innovative urban development that aims at sustainable development and high quality of life (Dirks & Keeling, 2009; Toppeta, 2010; Washburn et al., 2009). There are abundant studies on political and technological strategies to make smart cities, however, the changes induced by those strategies have not been comprehensively understood. In this regard, the purpose of this paper is to identify the results of smart city development using the systematic literature review method. We reviewed 55 papers and found 12 positive and 4 negative results are frequently mentioned. Among 12 positive results, six were purely hypothetical without any evidence: (1) enhancing citizen involvement, (2) protecting the environment, (3) facilitating social development, (4) facilitating sustainable development, (5) fostering innovation, and (6) increasing social capital. There is relatively less attention to negative results. Two out of four negative results are purely hypothetical: (1) privacy and security issues and (2) diminishing freedom of speech and democracy. Further studies are needed in discovering the evidence for purely hypothetical impacts and comparing smart city development in advanced and emerging economies.

Keywords: smart city, ICT, urban planning, result, systematic literature review

2.2 Introduction

Although the definition of 'smart city' is still developing, it is agreed among scholars that the major feature of a smart city is the use of information and communication technologies (ICT) (Anthopoulos, 2017; Komninos & Mora, 2018; Yigitcanlar et al., 2018; Zygiaris, 2013). ICT-embedded urban systems that use sensors, real-time monitoring, and a digital knowledge-sharing platform facilitate more efficient and effective urban management (Komninos & Mora, 2018). Smart cities also highlight the presence of high-quality human and social capital (Hollands, 2008) as well as the importance of smart governance (Lopes, 2017; Scholl & AlAwadhi, 2016). In general, the smart city is an innovative urban development that aims at sustainable development and a high quality of life (Dirks & Keeling, 2009; Toppeta, 2010; Washburn et al., 2009).

Several systematic literature reviews have been conducted on smart cities. Cocchia (2014) investigated studies on the smart city and digital city from 1993 to 2012 and identified similarities and differences between those two concepts. Over time, the definition of smart city embraced the definition of digital city. Although the review acknowledged that smart or digital cities are derived by the empirical implementation of technology, it did not mention the consequences of that implementation. Anthopoulos (2015) identified seven application domains of smart cities: resource, transportation, urban infrastructures, living, government, economy, and coherency. In doing so, he mainly laid the foundation for theoretical structure. Meijer and Bolívar (2016) provided a comprehensive review on smart urban governance. They concluded that smart city governance is a novel form of human collaboration using ICT, which also contributes to smart city theory. Trindade et al. (2017) analyzed the smart city concept in association with sustainable development. More recently, Komninos and Mora (2018) reviewed the smart city literature from 1992 to 2012 and explained how the smart city concept and research field have emerged. They also outlined what the three main dimensions that structure the smart city literature are. These dimensions represent a technology-driven vs. a human-driven approach, top-down vs. bottom-up planning, and collective intelligence vs. data-driven intelligence. These researches help to understand how the smart city concept has emerged and developed, how it is different from other similar concepts such as digital city and sustainable city, and how smart city principles are applied in different policy domains within cities. However, the available systematic literature reviews do not pay explicit attention to the results of smart city development. What kinds of results are expected and realized from implementing a smart city?

Although there are abundant studies on political and technological strategies to make smart cities, the changes induced by those strategies have not been comprehensively understood. In other words, knowledge of the results of smart city development are scattered and only partly discussed. In the current literature, there is no overview and analysis of what positive and negative results smart cities bring. In this regard, the purpose of this paper is to map the results of smart city development using the systematic literature review method. This review aims to provide insights into the results of smart city development, either positive or negative and hypothetical or observed. This can provide valuable information to researchers for further research directions on smart cities as well as to decision-makers and citizens who are interested in understanding and assessing the potential positive and negative effects of smart city developments.

This paper is organized as follows. After explaining procedure and result of the systematic literature review, this paper provides definitions and core characteristics of smart cities identified in selected articles. Then it categorizes results based on two standards: positive or negative and hypothetical or observed. Based on this categorization, the kinds and characteristics of results are explained. Finally, it concludes with a brief summary and discussion on the main findings as well as the limitations and implications of this research.

2.3 Purpose and Review Agenda

The purpose of this systematic literature review is to identify and analyze the results of smart city development. For this purpose, we followed three areas of interest: conceptualization, types of results, and kinds and characteristics of the results. First, conceptualization is the definition of a smart city. It concerns how the authors of the selected paper define the smart city. This is to see whether the results of smart city development are already included in the conceptualization. The second area of interest is the types of results which are categorized into four: hypothetical positive results, observed positive results, hypothetical negative results, and observed negative results. We tried to analyze the types of results with fields of study and country of the case study (by income groups and regions) to see which types of results are dominant in which fields of study or country. Thereby, this review can provide an overview of the results of smart city development in current literature. Finally, the third area of interest is the kinds and characteristics of each result. Each result is analyzed further, focusing on how frequently they appeared in papers and how they are framed in each paper. We tried to identify any inconsistencies in the results so that we can provide further knowledge gaps and future research agendas.

2.4 Methodology

2.4.1 PRISMA Protocol

A systematic literature review is useful when there seems to be a lot of dispersed knowledge but actual evidence is little provided. It is also beneficial when there are unanswered research questions (Petticrew & Roberts, 2008). The present state of smart city research is that there have been many studies, but the knowledge on their result is scattered and fragmented. A systematic literature review can bring these scattered pieces of knowledge into comprehensive analysis (Petticrew & Roberts, 2008). Among various methods, this study adopts 'Preferred Reporting Items for Systematic Reviews and Meta-Analyses' (PRISMA). Based on the protocols of PRISMA, literatures for systematic review were selected only if the following eligibility criteria were satisfied: field of study, topic, research method, language, publication status and database, and publication year.

Fields of study that encompass smart cities include computer science, engineering, social science, and urban planning. Because the research question concerns smart city development according to a holistic urban development strategy, this review focuses on the social science and urban planning context. Computer science and engineering are excluded because they mainly focus on developing new technologies or systems for smart city development. The literature in these fields already assume the results of smart city development as desirable outcomes (mainly benefits of ICT such as efficiency) and put more focus on instruments such as technologies, system design, and platforms to achieve those goals. In contrast, literature in the social science and urban planning fields provides a more comprehensive outlook from smart cities from methods involved in developing one to management and the (expected) results of such developments.

The topic is smart city development and its results. To be included, the articles should mention “smart city” or “smart cities” in their title, abstract, or keywords. Specifically, the articles should mention expected or observed results, performance, or changes induced by smart city development. The articles that focused on specific urban sectors such as economy, governance, or transportation are also included if they provide insight on results of smart city implementation.

If the article satisfies the field of study and topic, no specific research method is excluded. Theoretical, empirical, qualitative, or quantitative researches are all included. And only English written articles were included. Other languages were excluded because of difficulties in translation and interpretation.

The articles are peer-reviewed journal articles or full-article proceedings collected from Scopus and Web of Science. The search scope of these two digital archives is commonly used for an academic literature search. Google Scholar is also widely used; however, it is excluded here because it shows a variety of documents, not only academic articles but also commercial reports and news articles. When searching “smart city,” Scopus showed 12,677 documents and Web of Science showed 7,701 documents, but Google Scholar showed 65,700 documents.

According to the systematic literature review of Cocchia (2014), the smart city literature has been growing since 2005 and has spiked since 2010. From 2010 on, articles on smart cities rapidly increased due to the active implementation of smart city projects initiated by international businesses such as IBM and CISCO. Therefore, the publication year of articles herein is limited to 2005 through 2017.

2.4.2 Process of Screening

Initial search was conducted on August 12, 2017, using Scopus and Web of Science. Following the eligibility criteria, 668 articles were identified from Scopus and 455 articles from Web of Science. In total, 966 articles were eligible for screening after excluding duplicates. The screening process took us about two months until December 2017, and reviewing was performed afterward until June 2018. Figure 2.1 shows the flow of the screening process.

The first screening was based on the title and abstract. A substantial number of articles (708) were excluded because they were not relevant to the purpose of this article. The initial search included any articles that contained the word "smart city" or "smart cities" in their title, keywords, or abstract, which resulted in huge volume initially. The reasons for exclusion were 1) irrelevant topic such as smart shopping or smart parenting (n=450); 2) irrelevant focus including developing a new technological framework or system for smart cities and measuring smartness but not mentioning the results, performances, or changes (n=215); or 3) not an article or not available (n=43). Excluding these articles, a total of 258 articles were eligible for the second screening.

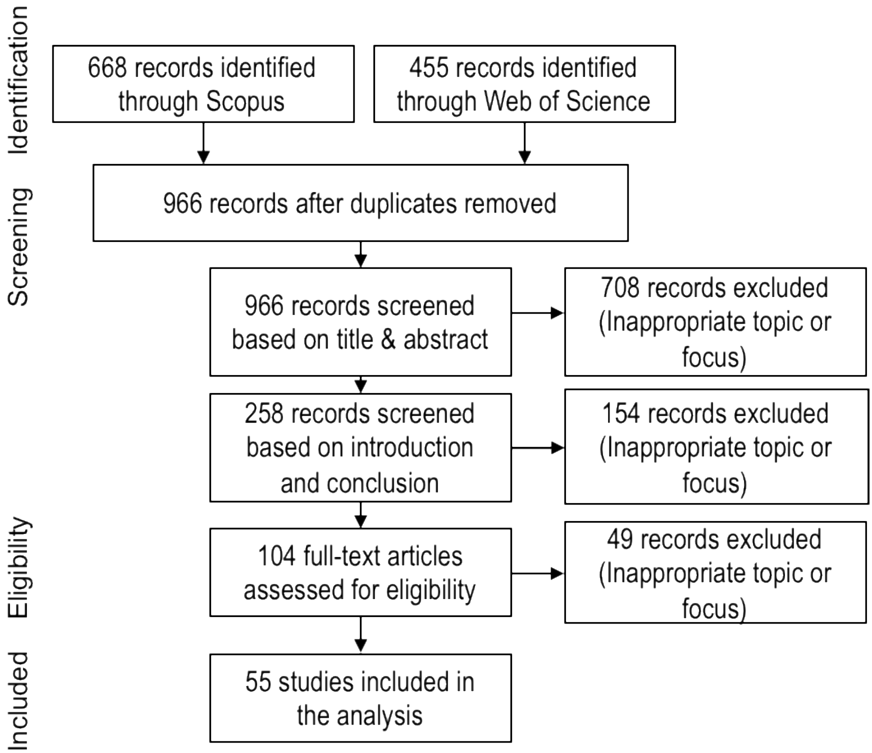


Figure 2.1 Process of Screening

The second screening of 258 articles was based on reading the introduction and conclusion. We assumed that if the results were not included in the introduction or conclusion, then the focus of the article was irrelevant to our review. In total, 154 articles were excluded. Those excluded dealt with smart city but their focuses were irrelevant (e.g., the role of competition or the smart city manager or the development of a new system design without mentioning its results or changes). The final screening on 104 articles was based on reading the full article. The article has to provide either potential or observed results or performances of smart city development. Among 104 articles, 55 were eligible for the analysis.

2.4.3 Characteristics of the Records

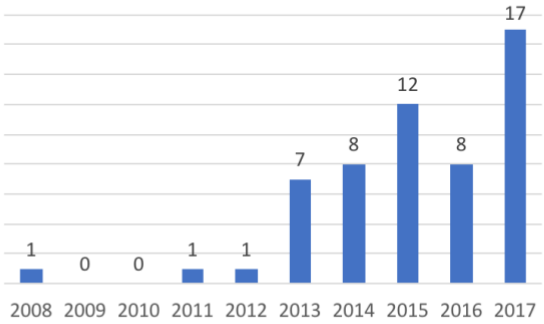
The selected articles have diversity among journals, fields of study, and publication years as shown in Table 2.1. First, there are 32 journals in which these articles are published, mainly in the field of Social Science. The fields of study are based on the initial categorization of Scopus and Web of Science. They can be categorized into four major fields: Business & Economics, Geography, Public Administration, and Urban Studies. Thirty-eight percent of the records come from the Urban Studies field. Articles in Business & Economics represent 27% and encompass Business Management, Economics, Econometrics, and Finance. Public Administration and Geography account for 22% and 13% respectively.

The oldest article was published in 2008, and the number of articles has gradually grown since 2013. Ninety-five percent of the articles were published in the last five years. This means studies on the results of smart cities are relatively new. Research methods are diverse because no specific methods are excluded if the article satisfies other criteria. The results showed that 85% of selected articles used qualitative methods while 15% used quantitative methods. Empirical studies account for 69% of the total and theoretical studies represent 31%.

Country means the case study country. Among 34 articles that conducted either a single case study or a comparative case study, a total of 33 countries were identified. The number of appearances of each country in the article is counted and the countries are grouped by their region and income level, following the categories of World Bank. Europe and Central Asia are the most frequently mentioned countries (51%). East Asia and Pacific countries account for 20% of the total, including South Korea (n=5), Australia (n=3), Singapore (n=2), Hong Kong, Malaysia, Taiwan, and Thailand (n=1, each). North America accounts 16%. Others (13%) include South Asia (India, n=2), Sub-Saharan Africa (Kenya, n=2), Middle East & North Africa (Saudi Arabia, n=1 and UAE, n=2), and Latin America & Caribbean (Brazil, n=3). Not surprisingly, the case studies are mainly focused on high-income countries (84%). Upper-middle-income countries represent 11% of the total while lower-middle-income countries account for only 5%. None are from low-income countries.

The selected articles show different characteristics. Most of them were published in the field of Urban Studies within the last five years. The majority of selected articles are based on qualitative research, and two-thirds of them are based on empirical study. The case studies are focused on advanced, high-income countries, mainly in Europe and North America. This is because smart city development requires certain levels of urban and technological development (Debnath et al., 2014), which are often insufficient in low-income countries.

Table 2.1 Characteristics of the Records

Criteria		Category	No	%
Field of Study		Urban Studies	21	38%
		Business & Economics	15	27%
		Public Administration	12	22%
		Geography	7	13%
Publication Year				
Research Methods		Qualitative	47	85%
		Quantitative	8	15%
		Empirical	38	69%
		Theoretical	17	31%
Country of Case Study	By Region	Europe & Central Asia	38	51%
		East Asia & Pacific	15	20%
		North America	12	16%
		Others	10	13%
	By Income	High Income	63	84%
		Upper-Middle Income	8	11%
		Lower-Middle Income	4	5%
		Low Income	0	-

2.5 Conceptualizing Smart Cities

Before we turn to the topic of result, we first study how smart cities are defined in the selected literature sample. We do this because we want to see whether attention is already paid to results in defining the concept of smart city. Among 55 selected articles, 38 of them provided a clear and explicit definition.

When taking a closer look at the definitions, we can identify 14 reoccurring factors as shown in Table 2.2. We categorized our definition into three factors: components, performance, and goals. Components are core requirements of smart cities, while performances are the result or outcome of smart city development. Goals are the aims of smart cities. When we first looked into these components, ICT infrastructure appeared 35 times and human, social, and institutional capitals also appeared 35 times in sum total. These tendencies show that the selected articles acknowledge that ICT infrastructure and human, social, and institutional capital play key roles within smart cities.

Table 2.2 Factors in Smart City Definitions

Factors		No. of Articles
Components	ICT Infrastructure	35
	Human Capital	16
	Institutional Capital	12
	Social Capital	7
Performance	Innovation	12
	Efficient Urban Management	11
	Citizen Involvement	6
	Collaboration & Partnership	5
	Democratic/Participatory Governance	3
Goals	Economic Growth & Competitiveness	15
	Sustainable (Urban) Development	13
	High Quality of Life	13
	Social Improvements	9
	Environmental Sustainability	9

Another interesting observation is that scholars have already paid explicit attention to the positive result of smart cities in their definitions.

These definitions mentioned that innovation, democratic governance, efficiency, citizen involvement, and collaboration can be realized or facilitated in smart cities by utilizing ICT infrastructure and human, social, and institutional capital. In particular, innovation and efficiency are mentioned 12 and 11 times respectively in these definitions. These two traits are also major characteristics of ICT infrastructures (Bakici, Almirall, & Wareham, 2013; Dameri & Ricciardi, 2015; Marek, Campbell, & Bui, 2017; Russo, Rindone, & Panuccio, 2016).

Moreover, the definitions stated that sustainable development can be achieved in smart cities as can a high quality of life. These achievements seem to be the ultimate goals of smart city development. In some definitions, sustainable development was specified as economic growth and competitiveness (n=15), social development (n=9), or environmental sustainability (n=9). Here, the definitions put more attention on economic development than the others do.

From this analysis, two main points can be made. First, the selected articles emphasize the role of ICT infrastructures and human, social, and institutional capital in smart city development. Second, the selected articles conceptualize smart city with expected positive results. The next section explores the results of smart city development as identified in the selected articles.

2.6 Results of Smart City Development

2.6.1 Categories of Results

The results of smart city development can be divided into four categories based on two dimensions: positive or negative and hypothetical or observed (see Figure 2.2). The decision on whether the results are positive or negative was based on the view point of each article. Mainly, positive results include the benefits of developing smart cities, such as economic development and social integrity, while negative results are the costs or side effects, such as privacy violation. Hypothetical results mean speculative or expected changes that have not been observed by case studies. When the sentence explaining the result is in the future tense or uses auxiliary verbs like 'would, can, or may,' it is considered a hypothetical result. When the results are mentioned with evidence from empirical studies, they are considered observed results. We assumed that the evidence in the articles were true even though sometimes they can be subjective or biased. We focused on the results themselves because the aim of this research is to examine to what extent smart city results have been identified, not to verify the trustworthiness of research outcomes. Based on these dimensions, four main categories emerged: hypothetical positive results (HP), observed positive results (OP), hypothetical negative results (HN), and observed negative results (ON). There are some articles mentioning both positive and negative results as well as both hypothetical and observed results.

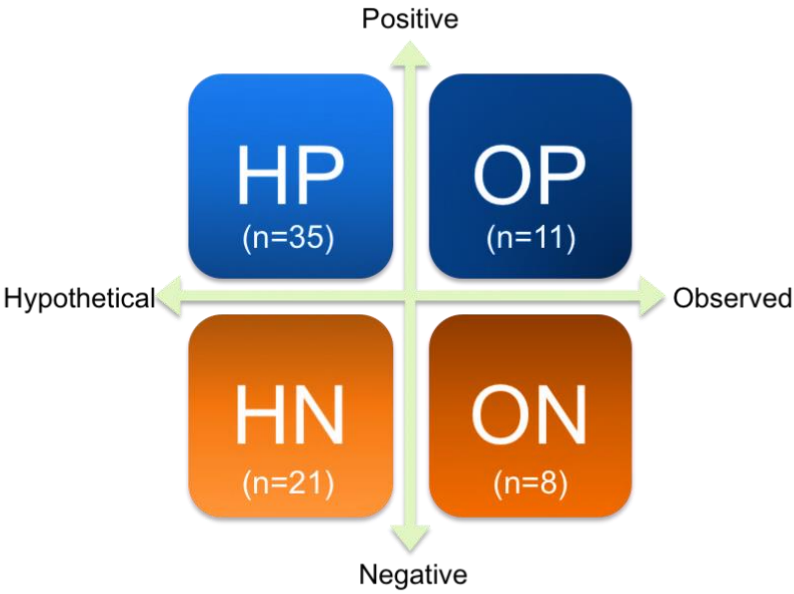


Figure 2.2 Categories of Results

Hypothetical positive results are mentioned in 35 articles while observed positive results appeared in 11 articles. Hypothetical negative results appeared in 21 articles and observed negative results are mentioned in 8 articles. It is clear that the articles are focused on hypothetical results as opposed to observed ones. Also, positive results have received more attention than negative results. Each field of study shows a different preference over results as shown in Figure 2.3. The articles published in the Business & Economics and Public Administration fields tend to emphasize the positive results. The Urban Studies and Geography fields are somewhat balanced between Administration advocate smart cities because the benefits are clear and relevant to those fields, namely economic competitiveness and efficiency.

On the other hand, Urban Studies and Geography may be balanced because they cover a wider range of topics, which results in a higher chance of including criticism of smart city development.

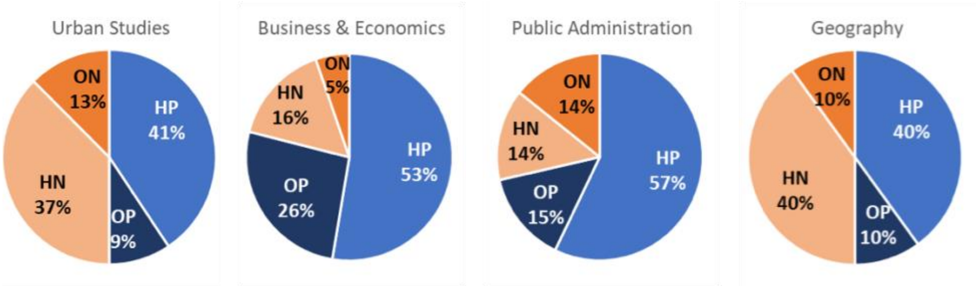


Figure 2.3 Results by Field of Study

The case study country also shows different ratios for each result according to income level and region as shown in Figure 2.3 and Figure 2.4. High-income countries tend to emphasize positive results over negative results while the upper- and lower-middle-income countries exhibit the opposite tendency. This means that smart city development is highly advocated in advanced countries that can afford high implementation costs and have sufficient technological expertise. Upper- and lower-middle-income countries often lack technological and institutional capital as well as the funding to implement smart cities. They are concerned that pushing smart city development can worsen existing urban problems such as poverty and inequality (Datta, 2015a, 2015b).

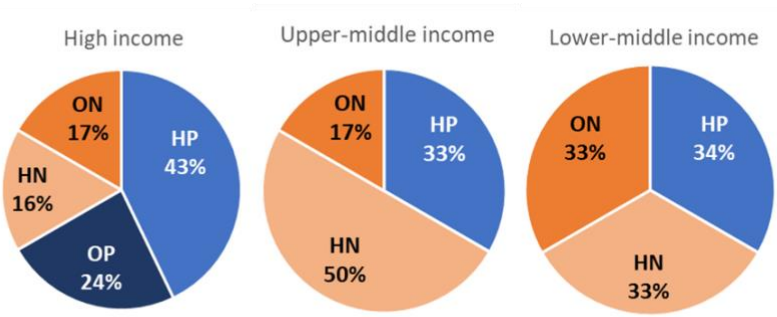


Figure 2.4 Results by Income Group

Positive results account for more than 50% of the total in Europe & Central Asia, North America, and East Asia & Pacific (see Figure 2.5). Europe &

Central Asia countries in particular have the highest ratio of hypothetical and observed positive results (71%). This is because smart cities are advocated as part of the European Commission's projects (Russo et al., 2016). North American case studies have the highest percentage of observed positive results (23%). Others include Latin America & Caribbean, Middle East & North Africa, South Asia, and Sub-Saharan Africa case studies. These are in the minority (10 case studies) but they show the highest percentage in negative results (69%). These countries are upper- or lower-middle-income countries, which also showed more negative results than positive ones.

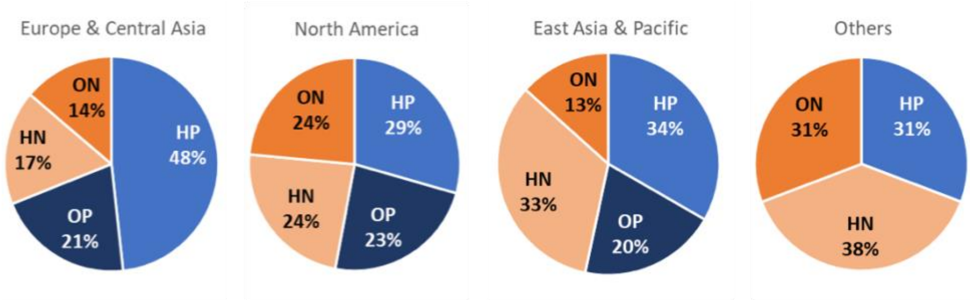


Figure 2.5 Results by Regional Group

To conclude, positive results more frequently appeared than negative results, and hypothetical results were emphasized more than observed results. The positive results are dominantly mentioned in all fields of study; however, Urban Studies and Geography showed more negative results than the others. Smart cities are advocated mostly in high-income countries, especially in Europe & Central Asia and North America.

2.6.2 Kinds and Characteristics of Results

In this section we take a closer look at the specific types of (hypothetical and observed) positive and negative results by analyzing the contents of the literature. In total, 12 positive and 4 negative results are found as shown in Table 2.3. Similar results are summarized into a single representative result. The positive results are closely related to the factors of smart cities that were identified in the definitions in the previous section.

Facilitating economic development and increasing efficiency are two main positive results of smart city development. Most of the articles precisely mentioned 'economic development,' while some explained it in detail with respect to the creation of new business opportunities and jobs (Capdevila & Zarlenga, 2015; Kraus, Richter, Papagiannidis, & Durst, 2015; Richter, Kraus, & Syrjä, 2015; Wiig, 2015), the enhancement of productivity (Angelidou, 2015; Kraus et al., 2015; Manitiu & Pedrini, 2016), the fostering of creative industries (Gil-Garcia et al., 2016; Kraus et al., 2015), service-oriented economy (Ménascé, Vincent, & Moreau, 2017) and increasing competitiveness in the global market (Dameri, Ricciardi, & D'Auria, 2014; Komninos & Tsarchopoulos, 2013). Efficiency is mentioned as a reduction in operational costs (Sarma & Sunny, 2017; White, 2016) and an improvement in the quality of public services and accessibility (Debnath et al., 2014; Welde, 2012). Increasing quality of life, protecting the environment, facilitating social development, and enhancing citizen involvement are mentioned 10 times each. Quality of life is analogous to increasing livability (Anthopoulos, 2017; Snow, Hakonsson, & Obel, 2016), material and physical well-being (Yeh, 2017), and tangible benefits for citizens (Wiig, 2015). Protecting the environment represents a reduction in CO_2 emissions and energy consumption (Debnath et al., 2014; Snow et al., 2016). Social development equates to becoming an equal and just society (Gil-Garcia et al., 2016; Komninos, Pallot, & Schaffers, 2013; Sajhau, 2017; Zygiaris, 2013). Finally, citizen involvement's appearance demonstrates that ICT can provide citizens with an opportunity to actively participate in the planning and decision-making process (Bakici et al., 2013; Gil-Garcia et al., 2016).

Good governance is summarized as easing decision-making (Bifulco, Tregua, & Amitrano, 2017; Nam & Pardo, 2014), increasing transparency (Gil-Garcia et al., 2016; Kitchin, 2014; Wiig, 2015), and facilitating democracy (Afzalan et al., 2017). Empowering citizen involvement represents informed citizens (Angelidou, 2015) and human capital (Angelidou, 2017a) as well as providing job training (Wiig, 2015) and increasing accessibility to the job market for socially marginalized people (Ménascé et al., 2017; Wiig, 2016). Facilitating sustainable development appeared seven times in the text as the smart city being able to forge urban sustainability (Angelidou, 2015; Sajhau, 2017). Smart cities can facilitate innovation by creating a smart cluster (Kraus et al., 2015) and living lab (Komninos et al., 2013). Enhancing cooperation means collaboration among stakeholders including government, the community, urban specialists, and businesses (Bakici et al., 2013; Nam & Pardo, 2014; Rabari & Storper, 2014). Increasing social capital appeared in the text as it is, without further explanation.

Table 2.3 Summary of Results

No	Results	Total	Hypothetical		Observed	
			Code	Total	Code	Total
P1	Facilitating economic development	25	5, 9, 20, 21, 22, 25, 32, 33, 35, 36, 37, 39, 45, 47, 48, 49, 50, 52	18	3, 4, 7, 27, 29, 38, 51	7
P2	Increasing efficiency of public services	23	2, 3, 4, 6, 9, 13, 16, 24, 32, 36, 37, 39, 42, 43, 47, 50, 51	17	5, 7, 20, 38, 41, 55	6
P3	Enhancing citizen involvement	12	3, 4, 9, 10, 24, 32, 42, 43, 48, 51, 52, 54	12	-	0
P4	Increasing quality of life	11	4, 9, 12, 13, 20, 32, 35, 42, 43, 44	10	38	1
P5	Protecting environment	9	2, 4, 5, 6, 16, 24, 33, 37, 43	9	-	0
P6	Facilitating social development	9	3, 9, 21, 32, 33, 37, 39, 45, 47	9	-	0
P7	Facilitating good governance	9	3, 8, 9, 10, 12, 33, 36, 54	8	41	1
P8	Empowering citizens	8	3, 21, 32, 34, 45, 48	6	29, 41	2
P9	Facilitating sustainable development	7	11, 12, 20, 32, 35, 43, 47	7	-	0
P10	Fostering innovation	5	3, 22, 39, 48, 49	5	-	0
P11	Enhancing cooperation	5	3, 5, 42, 50	4	41	1
P12	Increasing social capital	4	10, 11, 32, 48	4	-	0
N1	Aggravating/hiding existing urban problems	18	10, 11, 17, 26, 27, 30, 32, 33, 42, 46, 53	11	14, 15, 18, 21, 25, 28, 34	7
N2	Polarization & inequality	17	11, 12, 23, 26, 30, 31, 33, 38, 40, 42, 46, 53	12	14, 19, 21, 25, 28	5
N3	Privacy & security issues	9	1, 11, 12, 13, 14, 19, 23, 42, 48	9	-	0
N4	Diminishing freedom of speech & democracy	4	1, 13, 23, 53	4	-	0

It is interesting to see that citizen involvement, good governance, and social capital are mentioned as positive results because all three are already considered major factors of the smart city concept. Good social relationships and governance facilitate smart city development (Bakici et al., 2013; Capdevila & Zarlenga, 2015; Caragliu et al., 2009). At the same time, social and institutional capitals can be enhanced through smart city implementation.

Implementing ICT in a governmental organization can enhance cooperation among departments, foster greater interaction with citizens, increase public service efficiency, and facilitate good governance (Bifulco et al., 2017; Romanelli, 2013). It is a self-reinforcing mechanism. When looking at Table 2.3, it is obvious that hypothetical positive results are dominant. Hypothetical positive results account 86% of all positive results while observed positive results account for only 14%. Facilitating economic development and increasing efficiency of public services are the most frequently mentioned positive results in both a hypothetical and observed way. Table 2.3 also reveals that some results are only hypothesized and not observed (yet anyway), like: (1) protecting the environment; (2) facilitating social development; (3) enhancing citizen involvement; (4) facilitating sustainable development; (5) fostering innovation; and (6) increasing social capital. This is striking as concepts like social capital, innovation, and sustainable development are operationalized to a great extent in the various literatures. Perhaps it is difficult to prove a causal link between smart cities and these results because the underlying concepts are quite big and complex.

On the other hand, the existing literature already provides some proof of other results. We already mentioned increasing efficiency of public services and facilitating economic development, which hasn't gained much attention until now. In France, for example, Lyon increased its water provision efficiency and Nice reduced its waste collection cost by implementing smart technology (Sajhau, 2017). In Barcelona, smart city development created 55,000 jobs and 1500 new companies and institutions (Bakici et al., 2013). Enhancing citizen involvement and facilitating good governance are also observed in the case studies. The articles report them based on interviews. For example, enhancing citizen involvement was observed in Seoul and San Francisco, where open data and participatory service design stirred citizens' participation (Lee, Hancock, & Hu, 2014). Facilitating good governance could be found in Philadelphia, which adopted a smart emergency calling system that contributed to better decision-making with active citizen participation (Nam & Pardo, 2014). Finally, proof of an increase in quality of life is based on the secondary data such as official websites and reports as well as interviews. Based on these sources, the article concluded that the smart infrastructure and services contributed to enhancing not only the quality of citizens' life but also their overall satisfaction (Anthopoulos, 2017).

The negative results are relatively less mentioned than the positive results. They highlight the side effects of excessive use of ICT. What we can observe from Table 2.3 is that most of the negative results are related to use of ICT in smart cities. Polarization, digital divide, and inequality can occur in a smart city when the technology is unevenly distributed among regions and citizens (Bilbil, 2017; Caragliu et al., 2009; Klimovsky, Pinteric, & Saparniene, 2016; Neirotti et al., 2014; Rabari & Storper, 2014). Socially marginalized people who have less education and fewer digital skills can be excluded from the benefits of smart cities because they do not know how to use the technology (Mundoli, Unnikrishnan, & Nagendra, 2017; Söderström, Paasche, & Klauser, 2014). Also, smart city development can stigmatize certain areas by sharing open data (e.g., crime rate), making them less attractive for investments, which reinforces polarization (McFarlane & Söderström, 2017; Vanolo, 2016).

Smart cities are criticized as being a corporate-oriented vision because ICT is developed and promoted by big international companies (Letaifa, 2015; Hollands, 2008; Söderström et al., 2014). They try to sell a standardized solution, often neglecting urban complexity. This tendency is problematic because every city suffers from different problems. A standardized solution may not be able to solve the unique problems of different cities (McNeill, 2015; Söderström et al., 2014). Moreover, focusing on only a technological solution can conceal the real problem of the city (Grossi & Pianezzi, 2017) and ignore alternative measures (Hollands, 2015; Marek et al., 2017). In combination, all of this can result in aggravating or hiding existing urban problems. Also, smart cities try to connect everything into one network under their control, which leads to privacy and democracy issues (Galdon-Clavell, 2013). Because of the prevalent personal data collection in smart cities, citizens can be exposed to constant surveillance (Angelidou, 2017; Angelidou, 2017a). This affects how people behave and speak, which can reduce their freedom of speech and democracy (Vanolo, 2016). Similar to positive results, hypothetical negative results are more frequent than observed ones. The negative results without observed evidence are (1) privacy violation and security issues and (2) diminishing freedom of speech and democracy. This is surprising because privacy and security issues are often proclaimed but not (yet anyway) observed as a limitation of smart cities. Privacy and security issues are delicate issues, but they depend on how people perceive and treat their privacy (Elmaghraby & Losavio, 2014). Also, freedom of speech and democracy are highly subjective and culturally sensitive concepts that pose challenges in terms of clearly measuring them.

It is interesting to see opposite views on democracy and freedom of speech in smart cities regarding their positive and negative results. The articles advocating positive results state that smart city development can foster an open social environment and stir citizens' participation so that they can freely express their needs (Gil-Garcia et al., 2016; Komninos et al., 2013; Navarro, Ruiz, & Peña, 2017). On the other hand, criticisms warn that the main agents who gather and manage urban data are private organizations that are interested in revenue generation, which may disagree with citizens' benefit (Galdon-Clavell, 2013; Hollands, 2015; Vanolo, 2016; Yigitcanlar, 2015). Because neither side provided evidence, it will be interesting to investigate which case is true in what circumstance.

Two negative results have been observed in the research: 1) polarization and inequality and 2) aggravating or hiding existing urban problems. Polarization and inequality are reported in various cities using the secondary literature and observation of case studies. In Kansas City, the criminal prevention system stigmatized a certain area as dangerous, which enhanced inequality and the division brought on by property price, market investment, and social capital (Brannon, 2017). In Philadelphia, smart online learning modules failed to include low-literacy and low-job-skilled residents (Sajhau, 2017). In Dholera, the process of developing smart cities excluded socially marginalized groups (Datta, 2015b). Cyberjaya, Malaysia was criticized because it failed to provide social amenities, thereby neglecting the social needs of its citizens (Angelidou, 2017b). And Genoa, Italy chose to promote a living lab for its smart city instead of dealing with the real problem, flooding (Grossi & Pianezzi, 2017). Finally, in Australia, high implementation costs hindered local governments' ability to fully implement smart cities (Barns et al., 2017).

2.7 Discussion

The selected articles mostly conceptualize smart cities based on expected positive results generated by the implementation of ICT infrastructures. The role of human, social, and institutional capital is recognized but the primary emphasis is on the technology. Because ICT is a core characteristic of smart cities, technology-related positive and negative results in particular are identified from the selected articles.

Positive results are mostly related to the benefits of ICT implementation, while negative results revolve around concerns and criticism of ICT, for example, privacy issues. Both definition and positive results emphasized an increase in efficiency and economic development by utilizing ICT in urban sectors. These two increases are major benefits of smart cities that are also observed in the case studies. Nevertheless, negative results are a good reminder that not all cities need to peruse efficiency or economic development.

The smart cities are costly but long-term returns are unknown (Söderström et al., 2014), and usually city government has limited funding and resources. So, the city governments need to set their priorities and ask themselves: What is most important and wanted in our city? Without considering such questions and blindly believing that smart city development will make things better, problems may be created or aggravated as shown in Genoa, Italy (Grossi & Pianezzi, 2017).

What our review also delivers is that the results of smart city development are mostly hypothetical and positive. This is natural because the idea of a smart city is rooted in an urban growth and development agenda. The results that are purely hypothetical without any evidence account for six out of 12 positive results. No proof is yet provided for positive results like (1) protecting the environment, (2) facilitating social development, (3) enhancing citizen involvement, (4) facilitating sustainable development, (5) fostering innovation, and (6) increasing social capital. This conclusion makes it a sound conjecture that smart cities via systematic research have more to prove. Smart city implementation is relatively new and its results need sufficient time to be observed. However, some well-known smart cities such as Seoul, Barcelona, and Singapore (in this case, smart nation) adopted smart city projects in the 2000s. Studying these early cases can give us indications of how those efforts can turn into (intermediate) results.

Another conclusion is that there is relatively less attention paid to negative results. The negative results can be regarded as the byproduct of excessive use of ICT. Two out of four hypothesized negative results are not (yet anyway) observed by the research data. The negative results without observed evidence are (1) privacy violation and security issues and (2) diminishing freedom of speech and democracy. Again, the future research agenda should be more devoted to providing proof of negative results as well. However, this kind of research is not straightforward since the definition and measurement of results such as sustainable development, innovation, and democracy depend on the institutional and cultural circumstances of each individual city. Further research can be carried out to find the evidence of these results, whether they are different from city to city and, if so, what causes such differences. A final conclusion is that smart cities are emerging more in high-income countries than in emerging economies and that they tend to emphasize positive results. The governments of high-income countries invested research and implementation into smart cities. For example, the European Union invested in smart city development through EU Horizon 2020. Smart cities require high implementation costs and basic urban infrastructures (Debnath et al., 2014). As a result, it can be difficult for developing countries to implement them. Europe & Central Asia countries in particular have the highest ratio of hypothetical and observed positive results. In developing countries, it is mostly the negative results that are emphasized. Indian case studies are especially likely to express doubt on the effectiveness and due process of smart city development (Datta, 2015a, 2015b). However, the Indian government announced the building of 100 smart cities (Datta, 2015a), and other developing countries are interested in this idea. It will be especially interesting to investigate how developing countries implement smart cities (i.e., the expectations, conflicts, and challenges in doing so) and then compare the results with high-income and emerging economies.

2.8 Concluding Remarks

Smart cities allow pervasive use of ICT in various urban sectors, from transportation and utility deliveries to public administration and governance (Bifulco et al., 2017; Snow et al., 2016). Through a systematic literature review comprising 55 articles, this paper analyzed positive and negative results of smart city development, both hypothetical and observed ones.

As this paper is a systematic literature review, not an empirical study, it has embedded limitation. First, it covered only peer-reviewed articles and full article conference papers. There may be observed results in other literature like monographs, edited volumes, government reports, or project evaluation reports. Second, the selected articles are limited to urban-planning-related fields. Considering the core of smart cities is ICT, the Engineering and Computer Science studies can provide evidence of positive results, such as a reduction in CO_2 emissions.

Despite these limitations, this review provides a comprehensive overview of the available (empirical) researches regarding the results of smart cities. Our paper's contribution is that we have identified the results of smart city development along different dimensions: hypothetical or observed, and positive or negative. Reporting on the results of smart city development, we reported types and frequency of the results and how they are framed in selected papers. Moreover, to provide an overview of the current literature on smart city developments, we have analyzed the methodologies (empirical or theoretical) used as well as of the geographical distribution of the case studies (by income groups and by regions). It can provide insight into what to expect and what to consider when implementing smart cities.

To conclude, this research shows that we need more explicit research focusing on which results, both negative and positive, actually come about from smart city development. This research serves a scientific goal that gaining systematic insight and understanding on the smart city results, both negative and positive, and provides implication for future research direction. It also serves societal relevance: what are the potential positive and negative results of smart city development and which results are not realized yet which are important to consider before making strategies for smart city development.

We have a few recommendations for the future research agenda. First, further empirical studies are needed to prove the hypothetical results. Six out of 12 positive results and two out of four negative results are only mentioned hypothetically without empirical evidence. Future research can focus on providing empirical evidence of the results by case studies. Second, future studies can focus on the difference between high-income countries and lower-income countries in smart city development.

Clearly, the positive results are highlighted in high-income countries while the upper- and lower-middle income countries focus on negative results. It would be interesting to further understand and explain why smart city developments seems to bring about different effects depending on the development level of the country in which they are implemented. Finally, it would be interesting for future research to investigate how smart cities are developed and implemented (governance strategies) and to see which approaches account for good or poor performance in smart cities.

Chapter 3

What is the Impact of Smart City Development? Empirical Evidence from a Smart City Impact Index

Yirang Lim, Jurian Edelenbos, Alberto Gianoli. Article under review in the Journal of Urban Technology (Tailor and Francis). Submitted on 21st May 2020.

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Chapter 4

Smart Energy Transition: An Evaluation of Cities in South Korea

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4 Smart Energy Transition: An Evaluation of Cities in South Korea

4.1 Abstract

One positive impact of smart cities is reducing energy consumption and CO_2 emission through the use of information and communication technologies (ICT). Energy transition pursues systematic changes to the low-carbon society, and it can benefit from technological and institutional advancement in smart cities. The integration of the energy transition to smart city development has not been thoroughly studied yet. The purpose of this study is to find empirical evidence of smart cities' contributions to energy transition. The hypothesis is that there is a significant difference between smart and non-smart cities in the performance of energy transition. The Smart Energy Transition Index is introduced. Index is useful to summarize the smart city component's contribution to energy transition and to enable comparison among cities. The cities in South Korea are divided into three groups: (1) first-wave smart cities that focus on smart transportation and security services; (2) second-wave smart cities that provide comprehensive urban services; and (3) non-smart cities. The results showed that second-wave smart cities scored higher than first-wave and non-smart cities, and there is a statistically significant difference among city groups. This confirms the hypothesis of this paper that smart city development can contribute to the energy transition.

Keywords: smart city, smart energy transition, evaluation index, South Korea

4.2 Introduction

Smart cities are novel trend in the urban planning field that strives for comprehensive urban management and high quality of life (Nam & Pardo, 2011a; Neirotti et al., 2014). The major component of smart cities is advanced technology, such as information and communication technologies (ICT), Internet of Things (IoT), big data analytics, cloud computing, social networks, and artificial intelligence (Ng, Xu, Yang, & Lu, 2017; Paskaleva et al., 2017; Silva et al., 2018; Talari et al., 2017). Smart cities exploit these technologies to provide benefits to citizens. The embedded technology in smart cities enables gathering, processing, and sharing big data so that informed decision-making is possible (Silva et al., 2018), which eventually enhances efficiency of urban services (Giest, 2017). Meanwhile, these core technologies are already applied in various urban sectors apart from smart city development. For example, IoT is used to gather energy consumption data so that it can aid optimizing energy distribution and consumption (Talari et al., 2017). Since smart cities are a holistic approach to make cities a better place, employing smart city development is significant to the energy system. The urban energy system needs to move towards a low-carbon system because cities are responsible for major energy consumption and CO_2 emission (IPCC, 2015). This movement is called energy transition (Bridge, Bouzarovski, Bradshaw, & Eyre, 2013), which requires a change in both energy supply and demand (Rutherford & Coutard, 2014).

Technologies can benefit energy transition. For example, CO_2 can be converted to clean fuels with wireless control (Ou, 2018). A hybrid energy system that uses multiple renewable energy sources can be applied to reduce CO_2 emission, which can be automated by a neural network that enables self-learning (Ou & Hong, 2014). On the demand side, passive buildings are designed energy efficiently from the outset to automatically reduce energy consumption. ICT can be used to sense and monitor energy usage in buildings so that people can reduce energy consumption (Navarro et al., 2017). For transportation, an automatic vehicle location system which is enabled by a Global Positioning System (GPS) can be applied to reduce fuel consumption and travel time (Debnath et al., 2014), and sharing transport data can reduce congestion (Snow et al., 2016).

The use of core technologies in a smart city can increase energy efficiency and contribute to reducing energy consumption and CO_2 emission

(Geels et al., 2018; Hara et al., 2016) which in the end, supports the energy transition. Since the smart city and the energy transition share some common aspects, a smart city development can contribute to the energy transition.

There are studies on technological solutions such as big data analytics, self-learning, hybrid power systems for energy transition (Giest, 2017; Ou, 2018; Ou & Hong, 2014) and IoT, data management and governance, and a living lab for smart city development (Alam & Porras, 2018; Ng et al., 2017; Silva et al., 2018; Talari et al., 2017). These studies provide valuable ideas on an improved energy system and more efficient data management for smart cities. However, they have not been evaluated from a holistic view of smart city planning. A smart city is more than an application of technology (Hollands, 2008). It also pursues innovation in governance and community (Meijer & Bolívar, 2016; Snow et al., 2016) and comprehensive urban development. This paper focuses on the impact of the smart city development, particularly on the urban energy system and energy transition, within the view of urban planning. The major hypothesis is that smart city planning can contribute to energy transition and there is a significant difference between smart and non-smart cities in the performance of energy transition.

South Korea is an interesting case for this purpose because there has been a nation-wide effort for smart city development as holistic urban planning. The South Korean government invested in digitalization and ICT implementation since the early 2000s, announced the Ubiquitous-City (U-City) plan in 2004, and established the first smart city in Songdo in 2009. As for energy transition, the government set a smart grid testbed in Jeju Island in 2010. These efforts are not evaluated yet, and we intend to compare smart and non-smart cities in South Korea to identify the results of smart city developments in energy transition. The remainder of this paper consists of the following approach. First, we build a conceptual framework on smart city and energy transition. After reviewing the literature on smart city and energy transition, we link them and develop evaluation criteria to construct an index. Second, we introduce South Korea's planning history and policies regarding smart city development and energy transition. Then, we move on to our analysis, introducing the data collection, analysis methods and results. Finally, we conclude with a summary of the analysis and discussion.

4.3 Smart City and Smart Energy System

4.3.1 Smart City Concept

The smart city concept is fragmented and not (yet) agreed upon among scholars because each study has a different focus (Yigitcanlar et al., 2018). Recently, Kummitha and Crutzen (2017) conducted a systematic literature review and categorized four different focuses on the concept: (1) restrictive; (2) reflective; (3) rationalistic or pragmatic; and (4) critical. Restrictive and reflective views both emphasize technology (mainly ICT), data management, and IoT. The difference is the view on human capital. According to the restrictive view, human capital remains the same despite technological advancement. In contrast, the reflective view sees human capital can be improved through the technology. The rationalistic view positions human capital as a major driver of smart city development. Human capital interacts with technology and creates a smart city. Finally, the critical view argues that smart cities enlarge gaps between haves and have-nots and only benefit the elites. In this paper, we take the rationalistic or pragmatic view towards the smart city concept. We think both technology and human capital play an important role in the formation of a smart city.

A smart city is an urban planning method that aims to achieve sustainable development and high quality of life (Bakici et al., 2013; Nam & Pardo, 2011a; Toppeta, 2010; Wagner, Brandt, & Neumann, 2014). The core components of a smart city are technology, community, and policy and these three main components work together to achieve the desired outcomes (Yigitcanlar et al., 2018). A smart city is a process to achieve balanced and sustainable development (Trindade et al., 2017). In that process, the city's attributes (e.g., population, economic status, existing infrastructures) become assets that interact with the three core components to create solutions for environmental, social, economic, and governance problems (Hollands, 2015; Neirotti et al., 2014; Wiig, 2015).

Technology represents mainly ICT such as sensors, broadband and wireless networks, and mobile devices (Schaffers et al., 2011; Washburn et al., 2009). ICT functions as an enabler and facilitator of various actions and innovations in the smart city (Nam & Pardo, 2011a). ICT-embedded infrastructures enable gathering, processing, storing and sharing of real-time information. Such technologies create a ubiquitous connection between the stakeholders and infrastructures (Cimmino et al., 2014; Nam & Pardo, 2011a).

Information sharing and communication can be utilized for better urban services. The accessibility and availability of ICT in each urban sector represent important indicators of being smart (Nam & Pardo, 2011a). IoT, cloud computing, artificial intelligence, and big data are major examples of ICT in a smart city (Ng et al., 2017). However, a smart city is more than having cutting-edge technology (Hollands, 2008). Technology is a prerequisite that facilitates collaboration and cooperation among government agencies, community, businesses, and other stakeholders so that they can find an innovative solution to local problems and pursue sustainable growth (Nam & Pardo, 2011a). In that sense, community and policy play an important role in shaping a city into a smart one.

A smart community pursues creativity, social learning, inclusiveness, cooperation, and democratic decision-making (Nam & Pardo, 2011a). It identifies and brings the problems to planning process for better services and citizen-centric decision-making (Romanelli, 2013; Stratigea, 2012). For that social networks, online participatory tools, and e-governance can be utilized to encourage communities to join and enables mutual communication (Bakici et al., 2013; Gil-Garcia et al., 2016; Kanter, & Litow, 2009). The living lab is an example of a user-driven innovation that fosters citizen involvement in service development (Alam & Porras, 2018; Schaffers et al., 2011). Inevitably, citizens need the ability to exploit ICT infrastructure (Stratigea, 2012). This may result in a digital divide (Partridge, 2004), but inclusive governance can empower citizens through various training (Stratigea, 2012).

Policy paves environments in which technology can be applied and implemented in desired places and include the community in the planning process. This includes investment in R&D for ICT infrastructure, providing learning programs for citizens who are not used to ICT devices, and maintaining a good relationship with communities and businesses. The policy is not limited to regulations, laws or legislation (Yigitcanlar et al., 2018), it represents a favorable governance environment for smart city development. In the smart city, e-governance shows the capacity of the government to collaborate with inter-departments, citizens, and businesses via online participatory tools (Nam & Pardo, 2011a) to improve public services (Barns et al., 2017; Odendaal, 2003).

As these three components interact together, desirable outcomes are generated in smart cities. We are especially interested in the outcomes in the environmental sector. Since the major objectives of smart city development include achieving energy efficiency and environmental sustainability (Kylili & Fokaides, 2015), the energy sector can be considered the main domain that constitutes a smart city (Mosannenzadeh & Vettorato, 2014). The energy sector in the smart city focuses on reducing energy consumption and CO_2 emission (Debnath et al., 2014; Snow et al., 2016), which is closely related to energy transition to a low-carbon society. In the next section, we introduce current challenges in energy transition and need for integrating the smart city development and the energy transition.

4.3.2 Energy Transition and Smart Energy System

The energy system faces challenges, such as intermittency of renewable energy sources, high demand, and pressure to reduce CO_2 emission. It is efficient to tackle these challenges in a holistic manner rather than treating them separately (Calvillo, Sánchez-Miralles, & Villar, 2016). A radical change is desired because of a technological lock-in to the unsustainable energy system, which relay on the limited amount of fossil fuel (Seyfang & Haxeltine, 2012). This change, the energy transition, is a shift to a low-carbon society (Grubler, 2012). It requires utilizing renewable energy sources, developing efficient storage and distribution technology and strategies, and consuming less energy in daily life (Bridge et al., 2013). This system-wide change can be achieved with smart city development, which itself is a comprehensive change in the urban system.

The energy system consists of generation, distribution and storage, and consumption and smart city technologies can contribute to each process to increase energy efficiency (Shahrokni, Lazarevic, & Brandt, 2015) and reduce CO_2 emission (Calvillo et al., 2016). For energy generation, hybrid renewable energy sources can be introduced to tackle the intermittency issue and it can be optimized with an intelligent power controller (Ou & Hong, 2014). Small-scale energy production plants such as solar panels can be installed at homes and offices (Mosannenzadeh, Di Nucci, & Vettorato, 2017). The smart grid enables real-time and interactive information sharing on energy production and consumption (Calvillo et al., 2016). It consists of advanced metering infrastructures, energy storage systems, intelligent energy management systems, big data analytics that enable optimization of energy use on-demand, and enhances stable energy distribution. Energy consumption patterns can be monitored through smart metering and accumulated data can aid better decision-making (Giest, 2017; Silva et al., 2018).

The common ground of energy transition and a smart city is the data derived from ICT infrastructure. Big data management is important but there are barriers in implementation (Giest, 2017; Mosannenzadeh et al., 2017; Paskaleva et al., 2017). A universal platform is needed to share the data which increases implementation expenses. Lack of institutional capacity forces external experts to join and this makes decision-making even complex (Giest, 2017; Mosannenzadeh et al., 2017). Most of the time, data collection is operated at a national level, which is not a suitable localized solution (Giest, 2017). These barriers can be overcome by smart city planning, which is more than the technology itself. Smart city planning can provide a clear and long-term vision, a consistent policy environment, and encourage collaboration among the stakeholders (Mosannenzadeh et al., 2017).

4.3.3 Theoretical Framework

As the energy system changes, the stakeholders' roles are also changing. The government's role has expanded from energy producer to comprehensive system manager. The government produces energy, promotes innovation in technology, and facilitates citizen participation in a sustainable energy system. The community's role has also expanded from energy consumer to energy producer using a smart grid system. Table 4.1 compares smart city components' contributions to the energy system under both the traditional and the new system. The first column shows three smart city components and the first row shows three domains of the energy system.

The main hypothesis is that a difference exists between smart and non-smart cities regarding performance in the energy system. To check the hypothesis, evaluation criteria are developed as shown in Table 4.2. Technology includes renewable energy and a smart grid system. The community's contributions are civil initiatives in the energy sector, energy consumption, and participation in energy-saving behavior. Finally, policy includes an R&D budget for technology and rules and regulations on energy systems.

Table 4.1 Comparison of Smart City Drivers' Contribution to the Energy System

Smart City Drivers	Traditional Energy System: Energy Production	Traditional Energy System: Energy Distribution & Storage	Traditional Energy System: Energy Consumption	→	New Energy System: Energy Production	New Energy System: Energy Distribution & Storage	New Energy System: Energy Consumption
Technology	○	○	×	→	○	○	△
Community	×	×	○	→	△	△	○
Policy	○	○	△	→	△	△	△

○: High contribution, △: Moderate/partial contribution, ×: No direct contribution.

Another aspect to consider in smart city development is the city's inherent attribute. Each city has different urban characteristics (e.g., population and density, the local government's ability and economic status) that influence smart city development. For example, a certain population threshold and density are desirable in implementing ICT infrastructure. Additionally, a high density increases the possibility of an agglomeration economy that can foster innovation (Florida, 2005). The local government's ability to plan and execute the smart city development is important (Stratigea, 2012) as stable financing and consistent policy can support the development process. The existing built environment shows reserve space for the potential development of the city. The economic status of the city influences people's accessibility and affordability to smart services.

Table 4.2 Smart City Drivers' Contribution to the Energy Transition

Smart City Drivers	Contribution to Energy Transition
Technology	Renewable energy Smart grid
Community	Civil initiatives in the energy sector Energy consumption Energy-saving behavior
Policy	R&D budget for technology Rules and regulations on energy systems

These aspects equate to the potential inherent smartness of the city. We use the term 'inherent smartness' because these characteristics are not the result of smart city development. Rather, they are the assets accumulated over time, along each city's development path. These variables are not the measure of smart energy transition, but they are included in the analysis to demonstrate each city's relative inherent smartness which may influence the smart energy transition.

4.4 Smart City Development in South Korea

4.4.1 Smart City and Energy Policy

Smart city development is one of the national development strategies in President Moon's administration (Baek, 2017). Smart city development in South Korea started with informatization and digitalization, following the generalization of the internet in the early 2000s. The government then initiated the U-Korea Plan (2006–2010) and the U-City Plan (2009–2012) and launched 55 U-City projects (45 cities if duplicated projects in the same cities are deducted). 'U' stands for ubiquitous technology that enables unlimited network accessibility anywhere and anytime. The official initiation of U-City was 2006 when the Ministry of Information and Communication and the Ministry of Construction and Transportation signed a memorandum of understanding on U-City development. The main focus of the U-City was on technology and infrastructure (e.g., ubiquitous sensor network, wireless sensor network, CCTV, fast internet network, mobile environment, and public Wi-Fi). The sensors are implemented in roads, rivers, and major facilities to facilitate management. U-City provides service mainly on transportation information and security (surveillance through CCTV and emergency response).

At the same time, the government started to prepare for energy transition under the 'Low Carbon Green Growth' agenda. Aligning with the global trend, the government focused on sustainable economic development, especially green and eco-friendly transportation. The government launched the Guideline for Low-Carbon Green City (2009) focusing on the development of low-carbon green cities to overcome the climate change crisis. The Low-Carbon Green Growth Law (2010) was enacted to regulate compact cities, mixed land use, public transportation, new and renewable energy use, and the water and resource cycle. Additionally, the government initiated the National Smart Grid Vision (2009) and the National Smart Grid Roadmap (2010). At a glance, the government's smart city and energy transition efforts seem to be separated. They both fall under the Low-Carbon Green City agenda but U-City is focused on technology and on transportation and security infrastructure while the low-carbon green city projects focus on purifying and restoring the natural environment and promoting renewable energy. In addition, the government used energy transition as a means of economic development, ignoring actual energy transition within the general society (Yun, 2009).

U-City is a Korean prototype of a smart city. As the smart city concept evolved into a comprehensive urban management platform, the Korean government also expanded its U-City concept. The term 'smart city' slowly took over 'U-City' by the governments. Table 4.3 shows occurrences of the term 'smart city' and 'U-City (or U-eco city)' in the government's policy news, press releases, and policy documents collected from www.korea.kr. There is a clear transition from U-City to smart city according to the government. U-City began to appear in 2004 and has been in use since 2005 in press releases. The term 'smart city' was less used than 'U-City' but in some news articles or documents, both were used. Since President Park Geun-hye, 'smart city' has become the dominant term.

Table 4.3 Use of Terms 'Smart City' and 'U-Eco City' by Governments

Government	Year	Smart City	U-City (U-eco City)
Roh, Moo-hyun	2003–2008	18	114
Lee, Myung-bak	2008–2013	126	175
Park, Geun-hye	2013–2017	525	66
Moon, Jae-in	2017–Present	759	23

Source: www.korea.kr.

Table 4.4 summarizes the major difference between the U-City and smart city. Both U-City and smart city utilize technology but U-City focuses on the technology itself while the smart city focuses on technological functionality. U-City focuses on connected infrastructure while the smart city pays attention to human and social capital. The U-City's goal is urban informatization (i.e., implementing technology for efficiency). In contrast, the smart city's aim is urban intelligence (i.e., making the technology more accessible to the general public). When there is an urban problem, U-City tends to follow ready-made procedures, but the smart city diagnoses the problem and prescribes a solution based on the data. The initiatives show difference, evolving from a government-led, city-focused, top-down manner to a multi-stakeholder-led, citizen-focused, bottom-up manner. The citizen role has also expanded from mere service users to active service developers. Based on the lessons learned from U-City development, the South Korean smart city tries to provide multiple urban services and to include citizens and other parties.

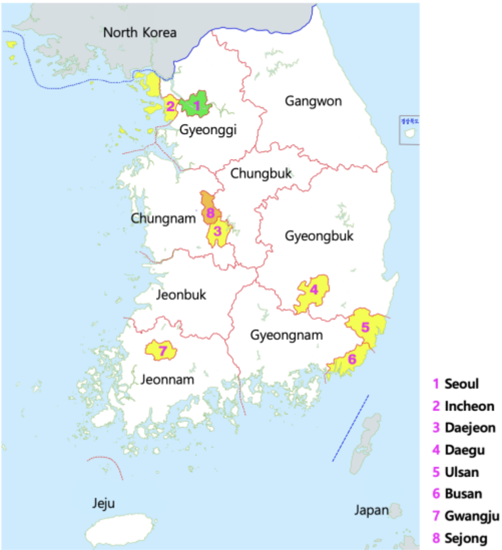
Table 4.4 Differences between U-City and Smart City

Category	U-City	Smart City
Major Focus	Connected infrastructure (network) Focus on technology	Social infrastructure (human and social capital) Focus on functionality
Goal	Urban informatization (efficiency)	Urban intelligence (usability)
Solutions to Urban Problems	Ready-made procedure	Prescription based on data
Initiative	Top-down City focused and government-led Vertical collaboration	Bottom-up Citizen participation and multi-stakeholder Horizontal collaboration
Implementation/ Operation	Limited urban services in telecommunication, security and disaster prevention Mostly implemented in newly developed cities Citizens adapt to provided urban services	Various urban services in administration, transportation, energy, water management, welfare, and environment Can be implemented in both new and old cities Provide citizen-centered urban services

Source: Adopted and translated from (Park, Gang, & Lee, 2018).

4.4.2 Smart Cities in South Korea

Administrative districts in South Korea consist of one special city, six metropolitan cities, eight provinces, one special autonomous city, and one special autonomous province (see Figure 4.1). The table in Figure 4.1. shows administrative districts in South Korea. The hierarchy of districts is Si/Do, Si/Gun/Gu, and Eup/Myeon/Dong. Si/Do represents special and metropolitan cities (Si) and provinces (Do). Si/Gun/Gu consists of sub-districts of Si/Do. Si and Gun are sub-districts of Do (provinces) and Gu is a sub-district of Si (Here, Si includes Special City, Metropolitan Cities, Special Autonomous City and cities (Si) under provinces (Do) that have a population of more than 500,000 people). The difference people). The difference between Si and Gun is one of population, wherein the criterion is 50,000 people. Eup/Myeon/Dong are sub-districts of Si/Gun/Gu. Here, we considered both Si and Gun as 'a city' (including the special city, metropolitan cities, the special autonomous city and cities under provinces). Including Seoul, Sejong, and Jeju, six metropolitan cities and 75 Si and 77 Gun, a total of 161 areas are considered as cities for data analysis.



Districts	Name	No. of Sub-District
Special City	Seoul (si)	25 (gu)
Metropolitan Cities	Incheon (si)	8 (gu) & 2 (gun)
	Daejeon (si)	5 (gu)
	Daegu (si)	7 (gu) & 1 (gun)
	Ulsan (si)	4 (gu) & 1 (gun)
	Busan (si)	15 (gu) & 1 (gun)
	Gwangju (si)	5 (gu)
Special Autonomous City	Sejong (si)	-
Provinces	Gyeonggi (do)	28 (si) & 3 (gun)
	Gangwon (do)	7 (si) & 11 (gun)
	Chungbuk (do)	3 (si) & 8 (gun)
	Chungnam (do)	8 (si) & 7 (gun)
	Gyeongbuk (do)	6 (si) & 8 (gun)
	Gyeongnam (do)	5 (si) & 17 (gun)
	Jeonbuk (do)	10 (si) & 13 (gun)
	Jeonnam (do)	8 (si) & 10 (gun)
Special Autonomous Province	Jeju (do)	2 (si)
Total	9 (do), 83 (si), 82 (gun), & 69 (gu)	

Figure 4.1 Administrative Districts in South Korea

Cities in South Korea can be categorized into three types as follows (see Table 4.5):

1) First-wave smart city (SC1): U-Cities developed from 2009 to 2013 and smart city projects by Korea Land and Housing Corporation (LH) and local governments focusing on transportation and security sectors.

2) Second-wave smart city (SC2): Smart city projects providing comprehensive urban management services, including transportation information, facility management, security and disaster prevention, health and welfare, administration, and environment (including ongoing smart city projects.

3) Non-smart cities (NSC): None of the above.

Table 4.5 Categorization of Cities

City Type		SC1	SC2	NSC
Metropolitan Cities (Including special districts)		Busan, Daegu, Gwangju, Ulsan, Jeju-do (5)	Seoul, Incheon, Daejeon, Sejong (4)	(0)
Do (Province)	Gyeonggi	Uijeongbu-si, Bucheon-si, Gwangmyeong-si, Pyeongtaek-si, Ansan-si, Goyang-si, Namyangju-si, Osan-si, Siheung-si, Hanam-si, Icheon-si, Anseong-si, Gimpo-si, (13)	Suwon-si, Seongnam-si, Yongin-si, Paju-si, Hwaseong-si, Yangju-si (6)	(12)
	Gangwon	Wonju-si, Gangneung-si, Samcheok-si (3)	-	(15)
	Chungbuk	Cheongju-si, Chungju-si, Jecheon-si, Jincheon-gun, Emseong-gun (5)	-	(6)
	Chungnam	Boryeong-si, Gyeryong-si, Hongseong-gun (3)	Cheonan-si, Asansi (2)	(10)
	Jeonbuk	Jeonju-si, Wanju-gun (2)	-	(12)
	Jeonnam	Yeosu-si, Naju-si (2)	-	(20)
	Gyeongbuk	Gyeongju-si, Gimcheon-si, Gumi-si, Yeongju-si, Yeongyang-gun (5)	-	(18)
	Gyeongnam	Changwon-si, Jinju-si, Gimhae-si, Yansgsan-si (4)	-	(14)
Total		42	12	107

* The name of NSC is omitted from the table. Source: LH Smart city (http://www.lh.or.kr/lh_offer/business/bus3500.asp).

4.5 Methodology

4.5.1 Methods and Limitation

An index is commonly used to quantitatively measure certain phenomenon (OECD, 2008), in this case, smart energy transition. We adopted this method to summarize various smart city's contributions to energy transition that can ease the comparison and provide the relative position of cities at a glance. There are several limitations of this method, first the data may not be available for all indicators. This can be overcome by introducing alternative indicators or using existing data according to the indicator. For example, some of the variables lack the city level data but provincial data (accumulation of city data) was available. In this case, we use the average of provincial data (provincial data divided by the number of cities in that province) as the city data. Additionally, the index may over-simplify the phenomenon and mislead policy decision-making. However, a well-constructed index based on sound theories can provide insights on the overall tendency of the phenomenon that can support decision-making (OECD, 2008).

The methods are as follows. First, based on literature we introduce a Smart Energy Transition Index and its variables. The variables are aggregated with an equal weighting scheme based on the assumption from the literature. Then, descriptive analysis is operated showing the top 10 and bottom 10 cities to show a general tendency of the index. Then, the indexes of three city groups are compared to check the statistical significance. A sensitivity analysis is carried out to see the effect of altered variables due to data availability. Finally, the correlation test between the index and urban characteristic variables is conducted.

4.5.2 Constructing a Smart Energy Transition Index

The Smart Energy Transition Index was developed based on the theoretical framework in Section 4.3, having indicators in Table 4.6. Due to the limited data source, we had to alter some of the indicators which are marked with an asterisk (*). The following bullet points indicate how the data was collected and treated.

- Renewable energy production*: There is provincial-level data on renewable energy production but not at the city-level. We divided provincial data by the number of cities in each province. Renewable energy sources include solar, photovoltaic, wind, hydro, geothermal, and biomass power.

- Smart grid*: The data available for a smart grid is the energy storage system (ESS) and advanced metering infrastructure (AMI) supply which are available at provincial level so we divided the data by the number of cities in each province. In addition, we found data on smart grid projects at smartgrid.or.kr. as well as ESS projects from DOE Global Energy Storage Database. We use multiple sources of data to triangulate the smart grid penetration.

- Civil initiatives in the energy sector: There are three forms of civil initiatives: cooperatives, social enterprise, and town enterprise. It is possible to access the full list of these initiatives and extract the ones specializing in the renewable energy sector. Most of them support residents in installing or renting solar paneling.

- Energy-saving behaviors*: This represents how much people try to reduce energy consumption in their daily lives. The data comes from the social survey which asks whether people try to use public transportation, participate in recycling, use fewer disposable goods, buy eco-friendly goods, and participate in energy conservation campaigns. These questions are asked on a scale of 1 to 5 with 5 being they are always participating and 1 being never or not interested. All provinces except for Gangwon, Chungnam, Jeonnam, and Gyeongnam have city-level data on each energy conservation behavior (n = 87). Gangwon, Chungnam, Jeonnam, and Gyeongnam (n = 74) provide only provincial-level data. It is risky to remove all missing cases, so we used provincial-level data as each city's data.

- Energy consumption per capita: Energy consumption means electricity use. The Korean Statistical Information Service (KOSIS) provides city-level data on electricity usage and is divided into four purposes of use: home, public, service, and industry. We excluded industrial (agriculture, fisheries, forestry and mining, and manufacture) electricity use because those facilities are usually built outside the city. Only home, public, and service usage are considered. The total amount of electricity consumption is divided by the population.

- R&D budget for technology: The percent of R&D budget earmarked for technology (technology development, R&D and scientific technology in general) in the local government's annual budget is used.

- Rules and regulations: Elis.go.kr provides a full list of each city's current ordinances, rules, and regulations. We count the number of ordinances and rules that are related to energy. The titles that frequently appeared include 'Energy Basic Ordinance', 'Ordinance on Green Roof', 'Ordinance on Response to Climate Change', 'Ordinance on Low-Carbon Green Growth', and 'Ordinance on Renewable Energy Provision'.

- Urban characteristics: As discussed in Section 4.3, the variables of the inherent smartness of the city are included in the analysis. These variables are population, financial independence ratio (FIR), gross regional domestic production (GRDP) per capita, and urbanized area per capita. The population represents the city's size while GRDP per capita represents the economic status of the city. FIR shows to what extent the local government has the financial means to provide public services and the urbanized area represent the urban infrastructure and density of the city.

Table 4.6 Indicator for the Smart Energy Transition Index

Dimensions	Category			Indicator	Year	Unit
Technology	Renewable energy production *		(RE)	Provincial data divided by number of cities on renewable energy production	2017	TOE
	Smart Gird *	Smart Grid	(SG)	No. of ESS and smart grid projects	Up to 2018	unit
		ESS		Amount of total ESS	Up to 2017	kWh
		AMI		No. of AMI installation	Up to 2017	unit
Community	Citizen initiatives in the energy sector		(CI)	No. of civil initiatives specializing in renewable energy	Up to 2018	unit
	Energy-saving behavior *		(EB)	Average energy-saving behavior	2016	score
	Energy consumption		(EC)	Total amount of electricity use in houses, service sector and public sector per capita	2016	MWh
Policy	R&D budget for technology		(RB)	% of the budget for technology (scientific development)	2016	%
	Rules and regulations		(RR)	No. of local gov't regulations, laws or legislation regarding energy sector	Up to 2018	unit
Urban Characteristic	Population		(POP)	Population of city	2017	Ppl
	FIR		(FIR)	Financial independence ratio	2017	%
	GRDP per capita		(GRD)	Gross regional domestic production per capita	2016	Million KRW
	Urbanized Area per capita		(UA)	Per capita urbanized area (residential + commercial + industrial area)	2017	m^2

The indicators are normalized and accumulated with equal weighting, as shown in Figure 4.2, to calculate the Smart Energy Transition Index score.

$$Smart\ Energy\ Transition\ Index = \frac{1}{3}\{\frac{1}{2}(RE + SG) + \frac{1}{3}(CI + EB + EC) + \frac{1}{2}(RB + RR)\}$$

Where RE means renewable energy production, SG means smart grid (accumulated with smart grid projects, ESS and AMI installation), CI means civil initiative in energy sector, EB means energy-saving behavior, EC means energy consumption per capita, RB mean R&D budget for technology, and RR means rules and regulations on the energy sector. We chose equal weighting because three components of smart cities are equally highlighted in the literature (Yigitcanlar et al., 2018).

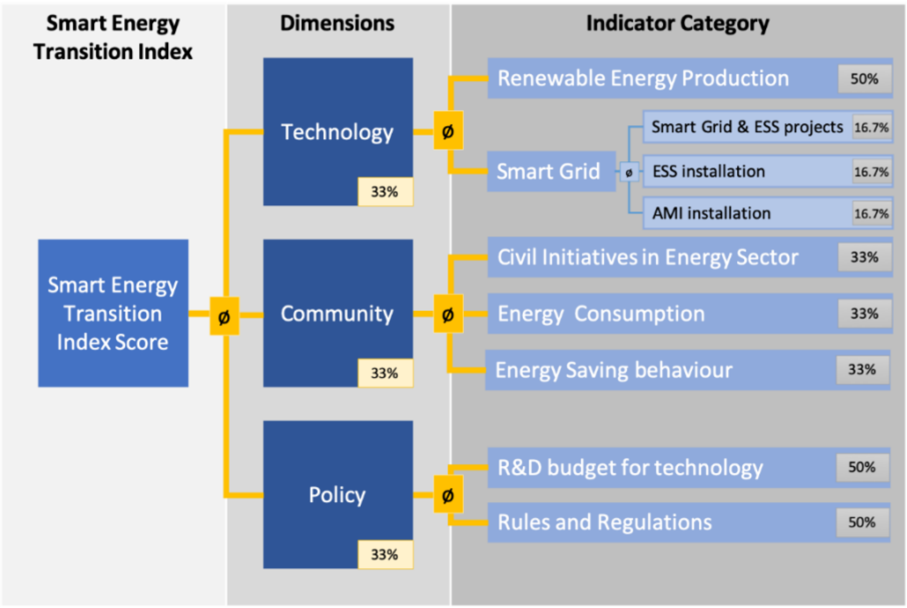


Figure 4.2 Constructing the Smart Energy Transition Index

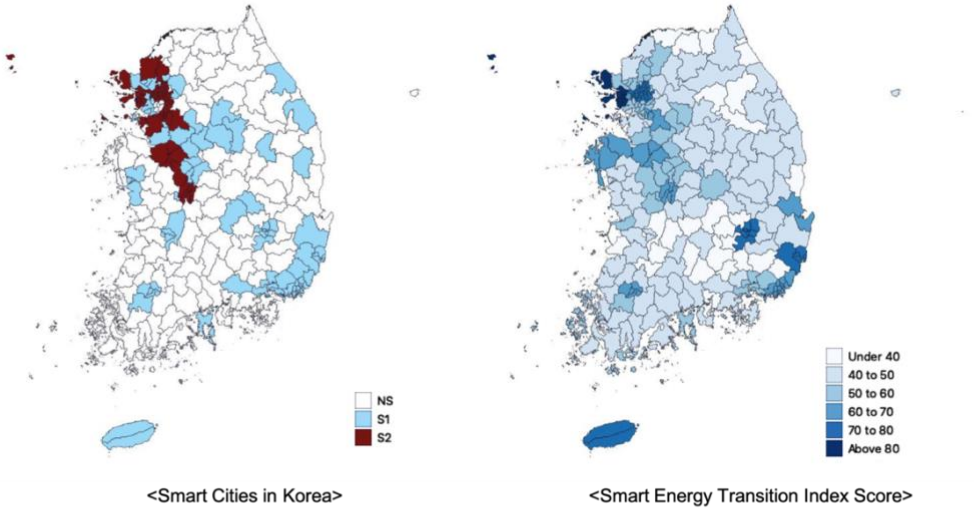


Figure 4.3 Smart Cities and Smart Energy Transition Index in South Korea

Since the indicators have different units of measurement, the indicators are normalized by using the z-score and percentile. Normalization puts all indicators on the same scale so each city's relative position can be shown. The z-score does so, where the mean is standardized to zero (0) and the standard deviation is converted to one (1). Then, z-scores are converted into a percentile in which the maximum value becomes 100% so that it is intuitive and easy to understand the score. Interpretation should be careful, 100% does not necessarily mean the city has perfect conditions for an indicator. For example, 100% in renewable energy does not mean the city's power source is 100% renewable energy. Rather, it means the city is relatively better than other cities. The Smart Energy Transition Index score ranges from 100% (highest) to 0% (lowest). Figure 4.3 shows the results of the Smart Energy Transition Index and the categories of cities in South Korea. Darker blue means a higher Smart Energy Transition Index score. In general, smart cities in South Korea have a higher Smart Energy Transition Index score than NSC.

4.5.3 Analysis

The 10 cities with the highest and lowest scores are shown in Table 4.7. The top 10 cities are mostly smart cities (SC1 and SC2) and the top eight cities are all metropolitan or special cities. These big cities have a large population, mostly more than 1 million people, and Seoul significantly exceeds the average (9.8 million). Jeju and Pohang-si have relatively lower populations but they have a higher per capita urbanized area. Incheon scores the highest followed by Seoul. Seoul scores similar to Incheon but it performs lower in the R&D budget for technology. Yongin-si is SC2 but a non-metropolitan city. It has a population of 1 million and fairly sound financial power as well as GRDP per capita. Yongin-si performs well in smart grid projects (95.4%) and community initiatives (76.8%) which compensates for its relatively poor performance in renewable energy production (32.6%).

Table 4.7 Top and Bottom 10 Cities

No	City Name	SETI Score	City Type	Population (ppl)	FIR (%)	GRDP per Capita (million KRW)	Urbanized Area per Capita (m^2)
Top 10 cities with highest SETI score							
1	Incheon	84.0	SC2	2,948,542	65.4	27.4	71.7
2	Seoul	76.8	SC2	9,857,426	85.0	36.5	37.7
3	Deagu	72.8	SC1	2,475,231	56.6	20.1	73.0
4	Ulsan	70.8	SC1	1,165,132	69.9	62.0	132.3
5	Jeju	70.0	SC1	657,083	39.6	25.9	109.5
6	Gwangju	69.6	SC1	1,463,770	49.2	23.2	82.1
7	Pohang-si	63.9	NSC	513,832	37.1	32.7	190.9
8	Daejeon	63.9	SC2	1,502,227	57.1	23.5	63.2
9	Yonhin-si	63.0	SC2	1,004,081	63.4	34.6	46.9
10	Bucheon-si	62.8	SC1	850,329	42.4	20.0	36.7
Bottom 10 cities with lowest SETI score							
161	Imsil-gun	27.3	NSC	30,162	15.8	25.0	206.8
160	Buan-gun	33.5	NSC	56,086	15.1	22.5	321.3
159	Seongju-gun	33.6	NSC	45,138	15.3	41.0	290.0
158	Wanju-gun	33.6	SC1	95,975	28.0	51.5	251.7
157	Jinan-gun	34.3	NSC	26,271	13.3	23.9	159.2
156	Sunchang-gun	35.1	NSC	29,698	16.3	25.0	94.4
155	Goryeong-gun	35.8	NSC	33,768	21.0	39.3	305.7
154	Gimcheon-si	36.7	SC1	142,908	29.5	34.1	213.2
153	Sacheon-si	37.9	NSC	114,252	22.6	34.7	262.2
152	Hapcheon-gun	37.9	NSC	47,000	14.9	19.0	138.1
-	Average	47.6	-	325,104	27.9	32.0	191.2

No	City Name	SETI Score	Average of						
			RE	SG	CI	EB	EC	RB	RR
Top 10 cities with highest SETI score									
1	Incheon	84.0	99.1	57.8	99.9	64.6	56.4	100.0	100.0
2	Seoul	76.8	95.0	68.7	100.0	74.4	56.3	43.4	100.0
3	Deagu	72.8	74.1	61.7	32.7	64.7	56.4	100.0	98.4
4	Ulsan	70.8	100.0	35.3	90.7	77.8	56.3	41.2	98.4
5	Jeju	70.0	99.4	41.2	84.8	48.3	56.3	74.7	78.6
6	Gwangju	69.6	40.8	52.6	94.7	53.7	56.4	89.3	98.4
7	Pohang-si	63.9	51.2	48.8	32.7	68.4	56.4	100.0	78.6
8	Daejeon	63.9	55.5	58.4	43.9	36.0	56.3	10.0	78.6
9	Yongin-si	63.0	32.6	95.4	76.8	61.8	56.3	41.2	78.6
10	Bucheon-si	62.8	32.6	88.2	76.8	41.6	56.4	41.2	78.6
Bottom 10 cities with lowest SETI score									
161	Imsil-gun	27.3	44.3	27.6	32.7	0.6	0.0	41.2	28.6
160	Buan-gun	33.5	44.3	27.6	32.7	0.3	56.3	41.2	28.6
159	Seongju-gun	33.6	51.2	37.7	32.7	13.7	56.4	41.2	2.7
158	Wanju-gun	33.6	44.3	27.6	32.7	2.8	54.7	41.2	28,6
157	Jinan-gun	34.3	44.3	27.6	32.7	7.0	56.3	41.2	28.6
156	Sunchang-gun	35.1	44.3	27.6	43.9	59.0	0.0	41.2	28.6
155	Goryeong-gun	35.8	51.2	37.1	32.7	33.5	56.3	41.2	2.7
154	Gimcheon-si	36.7	51.2	37.1	32.7	3.4	56.3	41.2	28.6
153	Sacheon-si	37.9	29.2	37.1	32.7	48.3	56.3	41.2	28.6
152	Hapcheon-gun	37.9	29.2	37.1	32.7	48.3	56.3	41.2	28.6
-	Average	47.6	47.0	45.9	46.6	49.2	54.9	44.8	47.8

The bottom 10 cities are mostly NSCs and from the 'Gun' area. Most of the bottom 10 cities have a relatively lower population and FIR. Additionally, their urbanized area per capita is higher than the average, meaning the urban infrastructures are spread. As a result, it is hard to implement ICT infrastructure. The bottom 10 cities scored poorly in each smart energy transition variable. Some cities showed very low scores in energy-saving behavior less than 10.0% and rules and regulations.

Exceptional cases are found in both the top and bottom 10 lists. One NSC is included in the top 10 list and two SC1s are included in the bottom 10 lists. A closer look into each one's smart energy transition and urban characteristic variables can explain the existence of these exceptional cases. Pohang-si, an NSC included in the top 10 list, performed well in energy-saving behavior (68.4%) and R&D budget for technology (100.0%). Pohang-si has a relatively smaller population but has sound FIR and GRDP per capita. In contrast, Wanju-gun and Gimcheon-si, the SC1s in the bottom 10 list, have a lower population, but their other urban characteristic variables are better than the average. Wanju-gun and Gimcheon-si have lower scores in each variable, similar to the other bottom 10 cities, but they scored even less in energy-saving behavior. This tendency implies that even though a city has higher inherent urban smartness rooted in urban characteristics, its smart energy transition may be more to do with active community involvement and voluntary participating in energy-saving behaviors. Additionally, the policy plays an important role in building a favorable environment for a sustainable energy transition.

Table 4.8 shows the results of the descriptive analysis on the Smart Energy Transition Index score of each city group and urban characteristic variables. SC1 is comprised of 42 cities and their mean Smart Energy Transition Index score is 50.9, with the minimum being 33.6 and the maximum being 72.8. SC2 is comprised of 12 cities where the mean score is 60.9 and the maximum score is 84.0. The number of NSCs is 107 and their mean score is 44.8. The minimum and maximum scores are 27.3 and 63.9, respectively. The mean score is highest in SC2 and lowest in NSC. SC2 has the highest average population, more than 1 million people, while NSC has the lowest population. This tendency can be observed in administrative-city-type metropolitan areas which are all smart cities with the highest populations, more than 2 million people. Meanwhile the Si area hovers around the average and Gun has the least population. FIR is also highest in SC2 and the metropolitan area and lowest in the NSC and Gun. The urbanized area per capita is lowest in SC2 and the metropolitan area, meaning the cities are more compact than in NSC or Gun. GRDP per capita does not show dramatic differences like other variables do, but the tendency is similar.

SC2 scored higher in most of the smart energy transition variables except for energy-saving behavior. SC2 scored especially high in technology variables (renewable energy production at 50.5% and smart grid projects at 64.5%) and policy variables (R&D budget for technology at 60.4% and rules and regulations at 77.1%). In comparison, in community variables, only civil initiative on energy is exceptional (63.3%). The others are similar or slightly higher than the average. SC1 shows somewhat better performance in community and policy variables than the average. NSC scored least, similar or lower than the average. The metropolitan area scored the most in every variable, exceeding the average.

Table 4.8 Descriptive Analysis

City Type	No.	SETI Score			Average of			
		Mean	Min	Max	Population	FIR	GRDP	UA
SC1	42	50.9	33.6	72.8	522,973	38.29	34.26	140.6
SC2	12	60.9	46.9	84.0	1,670,548	58.74	41.11	93.2
NSC	107	44.8	27.3	63.9	91,281	20.40	30.46	222.8
Metropolitan	9	69.4	54.8	84.0	2,646,685	61.49	29.06	90.1
Si	75	49.8	36.7	63.9	322,961	35.38	33.03	144.8
Gun	77	42.9	27.3	61.4	48,524	16.75	31.85	249.2
Total	161	47.6	27.3	84.0	321,605	27.93	32.25	191.7

City Type	No.	SETI Score	Average of						
			RE	SG	CI	EB	EC	RB	RR
SC1	42	50.9	45.7	53.1	50.5	50.4	56.3	45.1	57.0
SC2	12	60.9	50.5	64.5	63.3	49.6	56.3	60.4	77.1
NSC	107	44.8	47.0	40.6	43.3	48.6	54.2	42.9	40.8
Metropolitan	9	69.4	76.0	50.2	69.3	60.0	56.4	76.6	89.9
Si	75	49.8	41.9	53.7	49.7	46.8	55.6	44.3	57.5
Gun	77	42.9	48.4	37.3	41.0	50.2	54.1	41.5	33.3
Total	161	47.6	47.0	45.7	46.6	49.2	54.9	44.8	47.8

Si performed better than Gun except in renewable energy production and energy-saving behavior. To check whether there is a statistically significant difference among mean scores, one-way ANOVA is performed. One-way ANOVA is useful to check whether a difference exists among groups in terms of their mean. Before performing ANOVA, the following assumptions are checked:

1) The data for each group is normally distributed (normality).
2) The data for each group has a common variance (homogeneity in variance).

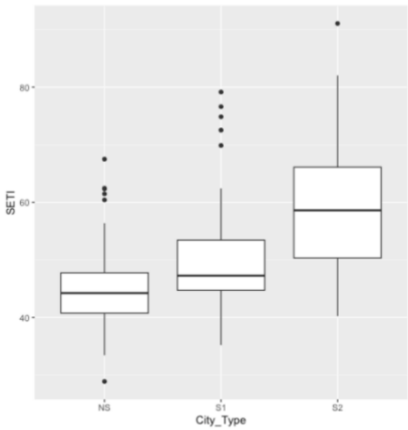
The result of the Shapiro test also shows that both non-smart cities and SC1s are not normally distributed (p-value < 0.05). For homogeneity of variance, Levene's test was performed. The p-value was less than the significance level ($p < 0.05$) which means the variance is not homogeneous. Since both normality and homogeneity in variance assumptions were not satisfied, the nonparametric test was performed instead of one-way ANOVA. Since the number in the group was three, the Kruskal-Wallis test was performed (see Table 4.9). Since the p-value was less than the significance level of 0.05, we can conclude that there are significant differences between the city categories. To find which pair of city category exhibit a difference, we performed pairwise comparisons using the Wilcoxon rank-sum test. SC2 is significantly different from SC1 and NSC ($p < 0.05$). Additionally, there is a significant difference between SC1 and NSC.

Table 4.9 Results of Levene's Test, Kruskal-Wallis Test, and Wilcoxon Rank-Sum Test

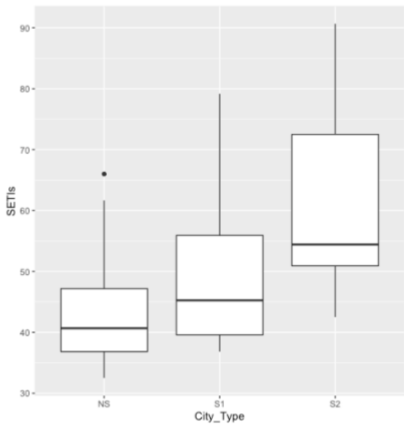
Levene's test	df	F-value	p-value
	2	8.9527	0.0002074 ***
Kruskal-Wallis	Chi-squared	df	p-value
	20.97	2	0.00002795
Wilcoxon rank-sum test		NS	SC1
	SC1	0.0030	-
	SC2	0.0005	0.0283

Signi. Code '***' : 0 ≤ *p*-value < 0.001., *p*-Value adjustment method: BH.

Since the data on renewable energy production and energy-saving behavior represents an estimation, we excluded these indicators for the sensitivity analysis. The adjusted Smart Energy Transition Index score is summarized below. The boxplot shows the revised SETI score has a wider range than the original one, but the general tendency is similar (see Figure 4.4). The results of the Kruskal-Wallis test and the post-hoc test can be interpreted the same as the original results (see Table 4.10 and Table 4.11). All in all, there is a significant difference between the city categories in the mean of their Smart Energy Transition Index scores.



(**a**) Original



(**b**) Adjusted

Figure 4.4 Boxplot and Distribution of Adjusted Smart Energy Transition Index Scores

Table 4.10 Descriptive Analysis of Adjusted Smart Energy Transition Index Scores

City	No.	Mean	Standard Deviation	Min	Max
SC1	42	49.8 (50.9)	12.1 (9.0)	36.8 (33.6)	79.2 (72.8)
SC2	12	60.8 (60.9)	15.5 (10.5)	42.5 (46.9)	90.7 (84.0)
NSC	107	42.9 (44.8)	6.9 (6.5)	32.5 (27.3)	66.0 (63.9)
Total	161	46.0 (47.6)	10.6 (8.8)	32.5 (27.3)	90.7 (84.0)

Note: Value within the bracket is the original.

Table 4.11 Adjusted Levene's Test, Kruskal-Wallis Test, and the Wilcoxon Rank-Sum Test

Adjusted Levene's test for homogeneity of variance and Kruskal-Wallis test			
Levene	df	F-value	p-value
	2	7.4145 (8.9527)	0.000836 *** (0.0002074 ***)
Kruskal-Wallis	Chi-squared	df	p-value
	24.791 (20.97)	2	0.000004138 (0.00002795)
Adjusted Pairwise comparisons using the Wilcoxon rank-sum test			
Pairwise comparison		SC1	SC2
	SC2	0.01395 (0.0215)	-
	NSC	0.01395 (0.0170)	0.00013 (0.0006)

Signi. Code '***' : 0 ≤ *p*-value < 0.001, *p*-Value adjustment method: BH.

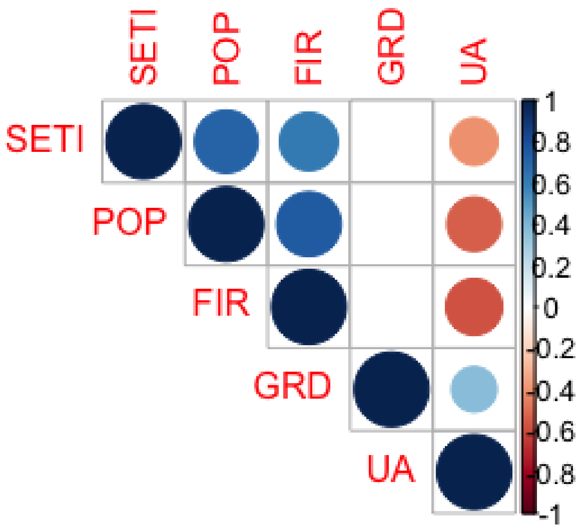


Figure 4.5 Correlation between SETI and Urban Characteristics

The analysis shows that a significant difference exists in the means of the SETI scores in each type of city. The top 10 highest scoring cities are mostly SC1 and SC2, and seven out of nine metropolitan cities (except Sejong and Busan) are on the list. This result seems to provide evidence that big cities with higher urban development levels are already ahead of other cities.

For the final analysis, we tested the correlation between urban characteristic variables and the SETI score to check the effect of urban characteristics. The result showed that the SETI score has a significant relationship with all urban characteristics variables except GRDP per capita (see Figure 4.5). Population and FIR have a high positive relation while per capita urbanized area has a negative relation. This result is plausible because technology, where urban infrastructure is reflected (smart grid), needs a population threshold to be implemented. Community is influenced by the size of the population, with more people likely to join community initiatives and participate in energy conservation behavior. Of course, a greater population results in more energy consumption. However, this is adjusted by using a per capita energy consumption level. The policy, especially R&D for technology, is closely related to the financial status of the local government, and hence, FIR. This propensity again confirms that inherent urban characteristics already determine the smartness of a city. On the other hand, a high per capita urbanized area means low density which results in more energy consumption (longer travel distance, spread sewerage pipeline, and longer electric wires) and a negative influence on the SETI score.

4.5.4 Findings of the Analysis

The major findings from the analysis can be summarized as follows. First, there is a significant difference in the mean of the index score by city type. This finding supports the hypothesis that smart cities perform better in the energy transition arena. SC2 performs better than SC1 or NSC in most of the smart energy transition variables except for energy-saving behavior. SC1 performs better than NSC, scoring similar to the average. This tendency can be also observed with the administrative city type. Metropolitan areas have a large population and high FIR score with Si's being modest and Gun's being the least. This takeaway provides another evidence of the first argument (i.e., urban characteristics influence the inherent smartness of the city). Metropolitan areas that already have resources at their disposal score higher than SC2 in their SETI score.

Second, there are some exceptional cases. Some SC1s performed poorly in smart energy transition while some NSCs performed better. This tendency is partly related to the urban characteristic variables and partly to the smart energy transition variables. For example, Wanju-gun and Gimcheon-si SC1s included in the bottom 10 cities, have a higher population and FIR than the other bottom 10 cities but it scored poorly in smart energy transition variables. Comparatively speaking, Pohang-si, an NSC included in the top 10 cities, scored high in energy-saving behavior and R&D budget for technology, even though its urban characteristic variables are lower than the other top 10 cities. Urban characteristics are important, but these exceptional cases also show the importance of smart city development that boosts community involvement and political support.

Finally, the correlation test shows a potential contribution of urban characteristic variables, such as population, FIR, and per capita urbanized area to the smartness of the city. Population and FIR have a positive relationship while per capita urbanized area has a negative relation to the index score. Per capita GRDP does not have a significant relationship. These findings imply that the inherent smartness of the city may influence the smart energy transition.

4.6 Conclusions

Smart city development aims for sustainable urban development and high quality of life (Nam & Pardo, 2011a; Toppeta, 2010; Wagner et al., 2014). This paper focuses on environmental sustainability, especially smart energy transition. A smart city can contribute to energy transition by properly compositing technology, community, and policy. By evaluating South Korea's smart city development, this paper endeavored to provide a framework for the Smart Energy Transition Index and empirical evidence on the effectiveness of smart city development. We developed an index with seven indicators that represent the possible contribution of three smart city components (technology, community, and policy). Urban characteristic variables (population, FIR, per capita GRDP, and urbanized area) are included in the analysis to determine the effect of the inherent smartness of the city. The results of the analysis can be summarized as follows.

- There is a statistically significant difference in the mean index score among city groups.
- SC2 scored the highest, followed by SC1, and NSC.

- There were exceptional cases where an NSC was included in the top 10 cities and two SC1s were included in the bottom 10 cities.
- There is a positive correlation between population and FIR with the index score, and a negative correlation between the urbanized area per capita and the index score.

What we can learn from these results is that smart city development can contribute to a smart energy transition. The fact that the mean SETI score of SC1s is lower than SC2s shows the limitation of SC1s, which mainly focus on technology implementation (Park et al., 2018). A smart city is more than technology (Hollands, 2008), and community and policy should also play important roles. The policy designs a favorable environment for community and technology to prosper, and active community involvement can boost smart energy transition. SC2 is an advanced model of SC1, one that attempts to balance three smart city drivers, and it has a bigger impact on realizing energy transition. Many of the SC2s in South Korea are still under a developing process. Especially, Busan and Sejong are designated as a national smart city testbed in 2018. The plan encompasses safety, transportation, environment, welfare, tourism, governance, and infrastructure. As smart cities evolve as a comprehensive plan, further studies are expected to trace their development and assess the impact on energy transition in the future.

Additionally, urban characteristics have an indirect influence on the smart energy transition. For example, a large population has an advantage in securing community initiatives, tax revenue for local government's financial status, and innovation that supports technology (Shen et al., 2018). The local government's ability (represented by FIR) can pave the way for a sustainable energy transition with financial and political support. These accumulated urban resources can positively influence smart energy transition.

The limitation of this study is that the dataset is imperfect. For example, renewable energy production is estimated from the provincial-level data and smart grid implementation is estimated with three different data sources. Lack of city-level data in some variables forced us to use alternative data (e.g., provincial data) which may not reflect the phenomenon correctly. Another limitation is that community-based smart cities are not considered. This is also due to the lack of such data. In addition, we provide only an overview of the smart energy transition in South Korea. Other countries may have different results. Despite these limitations, this paper still provides significant knowledge on the overall performance of smart cities on energy transition. We delivered an evaluation framework that combines smart city and energy transition. This is also significant as integrating the energy sector rather than treating it as separate entity provides flexibility in policy designing and planning (Lund, Østergaard, Connolly, & Mathiesen, 2017).

The future research can better composite the index with full city-level data, fill the knowledge gap on community-based smart city projects, and identify the effectiveness of smart city development on smart energy transition in other countries. Additionally, specific case studies can be carried out to examine the success and failure of smart cities in energy transition.

Chapter 5

Dynamics in Governance of Smart Cities: Insights from South Korean Smart Cities

Yirang Lim, Jurian Edelenbos, Alberto Gianoli. Article under review in the Government Information Quarterly (Elsevier). Submitted on 24th July 2020.

Cheonggyecheon, Seoul, Yirang Lim

Chapter 6

Conclusion

Part of conclusion section is submitted as a book chapter, in a book: Fransen, J., M.P. van Dijk and J. Edelenbos (eds.), New Paradigms in Urban Management, published by Edward Elgar Publishing, date of publication Spring 2021. Manuscript approved on 17th July 2020.

Geumganbyeon, Sejong, South Kroea, Yirang Lim

6 Conclusion

This thesis theoretically and empirically studies the impacts of smart city development on urban sustainability. It includes four academic articles. The first two articles are about the general impacts of smart city development on sustainable development. The first article is a theoretical study that finds positive and negative, hypothetical, and observed impacts from existing research. The second article is an empirical study measuring smart city development's overall impacts on economic, environmental, social, governance, and technological dimensions in South Korean cities. The third and fourth articles cover more specific impacts on the environment and governance. Both articles use South Korea as a case study. The third article focuses on environmental sustainability, especially the energy transition. The final article focuses on the governance model, how it changes according to the smart city development phases. This concluding chapter gives an overview of findings and relates them to the broader debates on smart cities. This chapter is constructed with four sections. The first section provides answers to the research questions. The main research question is specified with four sub-research questions, and each is answered. The second section explains the implications, and the third section provides limitations and future research agendas. The final section is the policy recommendations.

6.1 Answering the Research Questions

The overarching topic of this research is the impacts of smart city development on sustainable urban development. The main research question is, "What are the impacts of smart city development on urban sustainability?" This research question can be further specified into four sub-questions:

RQ1. How does the current smart city literature portray the impacts of smart city development?
- How do the selected articles conceptualize smart cities?
- What are the impacts of smart city development? Are they positive or negative? Are they hypothetical or observed?

RQ2. What are the overall empirical impacts of smart city development on urban sustainability?
- What indicators measure the positive and negative impacts in economic, environmental, social, governance, and technological dimensions?
- What are the observed impacts? Are they statistically significant?

RQ3. What are the empirical impacts of smart city development on environmental sustainability, especially the energy transition?
- What is the relationship between environmental sustainability, energy transition, and smart city development?
- Are smart cities better than non-smart cities in the performance of the energy transition?

RQ4. What are the empirical impacts of smart city development on governance?
- How do we identify the governance model empirically?
- How does the governance model change in different phases of smart city development?
- What is the appropriate governance model for developing smart cities?

6.1.1 How Does the Current Smart City Literature Portray the Impacts of Smart City Development?

Many studies conceptualize smart cities (e.g., Angelidou, 2015; Ching & Ferreira Jr., 2015; Nam & Pardo, 2011a; Neirotti et al., 2014), but smart city's impacts on urban sustainability lack comprehensive understanding. The first article (Chapter 2) aims to find the expected and realized impacts of smart city development from the current literature. It uses a systematic literature review method to identify, screen, and analyze the articles. Following the PRISMA protocol, a total of 55 articles are selected and analyzed. This research answers two sub-questions: 1) how do the selected articles conceptualize smart cities, and 2) What are the impacts of smart city development? Are they positive or negative? Are they hypothetical or observed?

1) How do the selected articles conceptualize smart cities?

Smart cities can be defined differently according to the agenda of involved actors (Haarstad, 2017). Even though the precise definition is missing (Caragliu et al., 2009; Dameri & Rosenthal-Sabroux, 2014; Thompson, 2016), the smart city concept evolved with some commonalities. There are 38 definitions from 55 selected articles. These definitions are analyzed with components, performance, and goals. We acknowledge there are far more articles about the smart city concept, and our samples are limited to that mentioning performance or the results of smart city development. However, this task is meant to see if there is already attention to impacts in the selected articles' conceptualization.

Components are what drives smart cities. Components include ICT infrastructure, human, social, and institutional capital. Especially, ICT infrastructure was mentioned the most among others. ICT is truly a core element in smart cities that enables various smart services and measures (Toppeta, 2010). Performance means smart cities' operation, partly expected results of smart city development, which includes innovation, efficient urban management, citizen involvement, collaboration and partnership, and participatory governance. In particular, innovation and efficiency were mentioned the most. It is natural because smart cities are an innovation ecosystem (Appio, Lima, & Paroutis, 2019; Schaffers et al., 2012), where efficient and optimal urban resource use is guaranteed. Finally, the goal is the purpose or achievement of smart city development. These are economic growth, sustainable development, high quality of life, social development, and environmental sustainability. Smart cities are viewed as one way to achieve sustainable development, especially economic prosperity (Marsal-Llacuna, Colomer-Llinàs, & Meléndez-Frigola, 2015; Toppeta, 2010).

The analysis on definition shows that conceptualization already includes the positive impacts of smart cities. This is why smart cities are so popular among decision-makers. Smart cities are attractive because 1) they provide technological solutions for social problems, 2) foster collaboration and innovation in governance, and 3) create political opportunities by making social consensus that smart development is a desirable goal (Haarstad, 2017). The smart city concept already assumes some of the positive impacts. However, we do not (yet) have a clear picture of the real positive and negative impacts of smart city development.

2) What are the impacts of smart city development? Are they positive or negative? Are they hypothetical or observed?

The article identifies 12 positive and four negative impacts (see Table 6.1). Among those impacts, six positive impacts and two negative impacts are backed up with empirical evidence. Observed positive impacts are 1) facilitating economic development, 2) increasing efficiency of public services, 3) increasing quality of life, 4) facilitating good governance, 5) empowering citizens, and 6) enhancing cooperation. The observed negative impacts are 1) aggravating/hiding existing urban problems and 2) polarization & inequality.

Table 6.1 Identified Impacts of Smart City Development

Impacts	Contents	C	F	H	O
Positive Impacts	1) Facilitating economic development	G	25		V
	2) Increasing efficiency of public services	P	23		V
	3) Enhancing citizen involvement	P	12	V	
	4) Increasing quality of life	G	11		V
	5) Protecting environment	G	9	V	
	6) Facilitating social development	G	9	V	
	7) Facilitating good governance	P	9		V
	8) Empowering citizens	P	8		V
	9) Facilitating sustainable development	G	7	V	
	10) Fostering innovation	P	5	V	
	11) Enhancing cooperation	P	5		V
	12) Increasing social capital	G	4	V	
Native Impacts	1) Aggravating/hiding existing urban problems	-	18		V
	2) Polarization & inequality	-	17		V
	3) Privacy & security issues	-	9	V	
	4) Diminishing freedom of speech & democracy	-	4	V	

C: Conceptualization, G: Goal, P: Performance, F: Frequency, H: Hypothetical, O: Observed

The positive impacts are, as suspected from conceptualization, based on the benefits of using technologies. Smart cities pursue optimizing the use of both tangible and intangible urban assets (Neirotti et al., 2014). Economic development, quality of life, protecting the environment, social development and social capital, and sustainable development are already mentioned as goals in the definitions. The rest of the positive impacts are also already mentioned as performance in the definitions. Like in the conceptualization, economic development and efficiency are the most frequently mentioned positive impacts. This confirms the fact that smart cities are conceptualized based on the optimism of techno-driven urban development. Smart cities are criticized for being technologically determined (Hollands, 2008) and techno-centric (Letaifa, 2015).

Indeed, smart cities can generate positive impacts. However, too much emphasis on technological solutions poses concerns on the negative impacts of technology. Negative impacts are deriving from the side-effects of technologies such as privacy invasion and polarization. Moreover, more negative impacts can be found in computer science literature. For example, Sharma and Park (2018) pointed out that the growing volume of data and the number of ICT devices in smart cities can be problematic. As more people, infrastructure, and devices are connected, technological problems can occur, such as bandwidth bottlenecks, high latency, privacy and security issue, and scalability of smart city networks (Sharma & Park, 2018). However, their research again suggests a new technological design to tackle these problems, reinforcing the emphasis on techno-centric vision.

Another interesting remark is the impacts are mostly positive and hypothetical. The number of articles mentioning hypothetical positive impacts is 35, while those of hypothetical negative impacts are 21. On the other hand, the number of articles stating observed positive impacts is 1, while the observed negative impacts are eight. Also, the positive and negative impacts are displayed differently by the field of study and country of the case study. Business and economics, and public administration emphasized positive impacts. It is because smart cities advocate economic development and efficiency in public administration, in which these fields are interested. On the other hand, more general fields such as urban studies or geography showed more negative impacts. When we look at the impact by country by income-level, high-income countries focused on positive impacts. In contrast, upper-middle- or lower-middle-income countries emphasized negative impacts. A survey from 2016 identified 1,119 smart cities. More than half of the cities are in Europe, North America, or Australia, where mainly high-income countries are geographically located (Thompson, 2016). High-income countries have the financial and technological capacities to implement smart cities. However, middle-income countries concern the adverse effects of smart city development. It is no surprise there was no case study with low-income countries. Smart cities are costly and require massive ICT infrastructure that low-income countries cannot afford. These findings open a new avenue for future research that more attention is needed to identify the actual impacts of smart city development by empirical studies, to focus on experiences of low-income countries, to find the difference in urban characteristics that influence the impacts.

6.1.2 What Are the Overall Empirical Impacts of Smart City Development on Urban Sustainability?

From the first article, we now know there is limited knowledge on the actual impact of smart city development (Komninos, Bratsas, & Kakderi, 2015; Lim et al., 2019a). Even though smart cities are related to realizing a sustainable urban future (Aelenei et al., 2016; Angelidou, 2015; Neirotti et al., 2014), there is a lack of evaluation framework to measure smart cities' contribution to sustainable development (Bibri & Krogstie, 2017). The second article (Chapter 3) focuses on finding empirical evidence of smart city impact on urban sustainability. It provides an evaluation index and compares the index results of South Korean cities. Based on the first article's findings, the impacts are categorized into four pillars of sustainability (economic, environmental, social, governance) and additional technological dimensions. The technological dimension is added because ICT plays a core role in smart cities. Indicators are identified from the literature review, and the data is collected from KOSIS, a Korean statistics information system. The index score is normalized with z-score and calculated by an equal weight scheme. This empirical study looks into the performance of South Korean smart cities and compares them with that of non-smart cities. The data set is established in 2008 and 2018 to compare the before and after the smart city development.

Cities are divided into first- and second-wave smart cities and non-smart cities. First-wave smart cities are Ubiquitous city (U-city) that focuses on implementing ICT infrastructure mainly in transportation and security surveillance sectors (42 cities). Second-wave smart cities are advanced from U-cities, acknowledging the smart city concept has evolved to comprehensive urban management (12 cities). In total, there are 54 smart cities, and 107 cities remain as non-smart cities. The categorization of first and second-wave smart cities is in line with theoretical categories of smart cities; smart city 1.0 and smart city 2.0 (Trencher, 2019). Smart city 1.0 is centralized and technology-centric, while smart city 2.0 is decentralized and citizen-centric.

The first-wave smart cities can be seen as the smart city 1.0 because they are initiated by the public agency, following a centralized process and distributing the technological solution. On the other hand, second-wave smart cities focus more on comprehensive development, acute to citizens' needs, similar to smart city 2.0. This research both contributes to the evolution of smart cities as well as empirical evidence of impacts. The second sub-question is divided into two: 1) What are the indicators to measure the positive and negative impacts in economic, environmental, social, governance, and technological dimensions; 2) What are the observed impacts? Are they statistically significant??

1) What are the indicators to measure the positive and negative impacts in economic, environmental, social, governance, and technological dimensions?

The variables account for positive and negative impacts from four dimensions of sustainability; economy, environment, social, and governance, and technology. The economic dimension includes two indicators: GRPD per capita and local income tax per capita. GRDP represents the city's productivity, while the local income tax indirectly reflects the city's income level (Lombardi, Giordano, Farouh, et al., 2012). The environmental dimension measures mainly energy use and CO2 emission level. It also includes citizens' participation in environmental saving behavior because citizen involvement is a crucial factor for environmental sustainability (Corsini, Certomà, Dyer, & Frey, 2019). Social dimension includes 1) general satisfaction on life that reflects the quality of life (Anthopoulos, 2017), 2) perception on the economic status that measures equality (Hara et al., 2016), and 3) employment rate of socially marginalized groups (low-educated and elderlies) which represents citizen empowerment (Wiig, 2016). The governance dimension measures citizen involvement with online participation and the number of citizen initiatives (Anthopoulos, 2017) and transparency and democracy by asking citizens' perceptions (De Wijs et al., 2016). Finally, the technological dimension concerns innovation by the number of patents, knowledge-intensive industries, and privacy issues.

Each indicator score is calculated for the years 2008 and 2018 to determine whether smart city development is contributing to urban sustainability. An increase in indicator score means the performance is getting better, which is considered a positive impact.

2) What are the observed impacts? Are they statistically significant?

Figure 6.1 visualizes each indicator's score in 2008 and 2018 by city type. The first and second-wave smart cities combined show a better performance in the economy, quality of life and equality, citizen involvement, and knowledge-intensive industries. On the other hand, some indicators are decreased in smart cities, including CO_2 emission, employment of low-educated and elderly, perception of government's transparency and democracy, and perception of information security. It means smart cities have both positive and negative impacts on urban sustainability. Environmental impacts are especially unclear since the indicators show different results. In second-wave smart cities, index scores for energy consumption and environmental protection behavior increased, but CO_2 emission was decreased. In first-wave smart cities, the index score for energy consumption increased, but environmental protection behavior and CO_2 emission were decreased. Smart cities can be both beneficial and detrimental to environmental sustainability. At least in advanced smart cities, citizens engage more in environmentally aware behavior (Corsini et al., 2019). However, smart technologies pose environmental risks such as increasing CO_2 emission due to excessive use of ICT infrastructure (Bibri & Krogstie, 2017). Songdo, the Korean model smart city, was subjected to strong opposition from environmentalist groups, both local and international. According to Shwayri (2013, p. 53), this smart city is "built on the destruction of precious wetlands, home to some of the rarest species on the planet, causing the disappearance of some."

The indicators of non-smart cities mostly remain at the same level or show slight change except for a decrease in satisfaction on life and perception on income level, and an increase in perception of information security. This tendency is opposite to that of smart cities. In smart cities, citizens feel their quality of life and equality are better, while citizens in non-smart cities feel worsened. Within each city type, smart cities show an increase in quality of life and equality, but this also implies that smart city development can accelerate polarization. Since non-smart cities' performance worsens, the gap between smart and non-smart cities extended to further division. It is already pointed out as negative impacts that polarization and inequality can be increased when the technology is unevenly distributed (Caragliu et al., 2009; Rabari & Storper, 2014). This claim is also confirmed by the way the South Korean government designates smart cities. According to the Third Smart City Master Plan, Busan and Sejong are designated as national smart city testbeds, which are already well-developed cities (MoLIT, 2019).

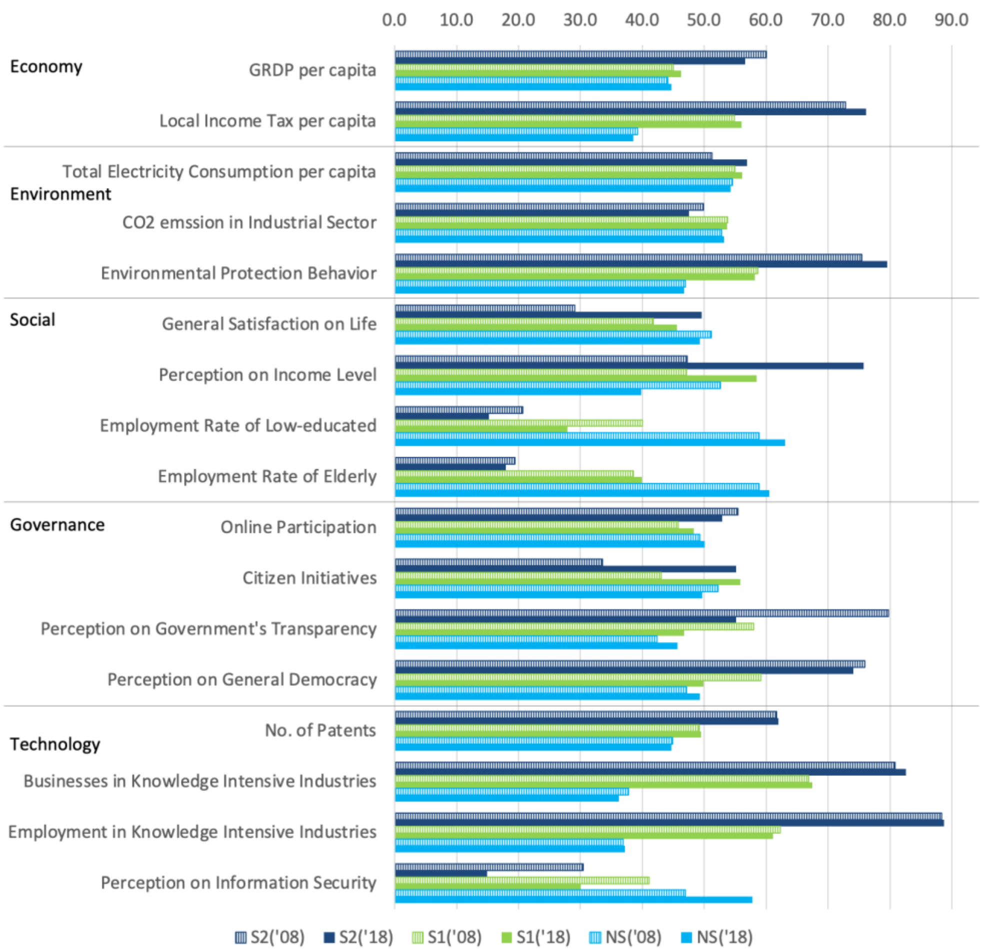


Figure 6.1 Indicators of Smart City Index by City Types
S2: Second-wave smart cities, S1: first-wave smart cities, NS: non-smart cities

Table 6.2 summarizes the positive and negative impacts that were found in the analysis. When the first- AND second-wave smart cities' performances are both increased in 2018 than in 2008, it is considered to be observed positive impact. The observed negative impacts are when the performances are decreased. If the first- and second-wave smart cities show different results, it is excluded from observed impacts. For example, indicator scores of GRDP per capita, employment of elderly, and online participation were decreased in second-wave smart cities and increased in the first-wave smart cities. Also, indicator scores of environmental protection behavior and employment in knowledge-intensive industries were decreased in first-wave smart cities and increased in second-wave smart cities. These conflicting results need further examination, which is beyond the scope of this research, so they are excluded from the table. The asterisk means that the impact is statistically significant by the difference in difference regression.

Table 6.2 Empirical Evidence on Positive and Negative Impacts of Smart City Development from South Korean Experience

Dimensions	Positive Impact	Negative Impact
Economy	- Increase in local income tax per capita	-
Environment	- Reduction in electricity consumption	- Increase in CO_2 emission in the industrial sector
Social	- Increase in satisfaction on life - Increase in satisfaction on income level*	- Decrease in employment of low-educated*
Governance	- Increase in the number of citizen initiatives*	- Decrease in perception of transparency* - Decrease in perception of democracy
Technology	- Increase in the number of patents - Increase in businesses in knowledge-intensive industries	- Decrease in perception of information security*

As shown in the table, smart city development both have positive and negative impacts on all five dimensions. In the economic dimension, local income tax per capita is increased, which backs up the claim that smart cities support economic development. Smart cities are innovation ecosystems (Appio et al., 2019) that encourage 'innovation for all' (Komninos et al., 2015). It is related to technological dimensions, where the numbers of patents and businesses in knowledge-intensive industries are increased. These indicators are essential parameters of innovation (Caragliu & Del Bo, 2018). In Europe, smart city policies also positively impacted innovation spillover (Caragliu & Del Bo, 2018). Smart cities also show a positive impact on the environmental dimension, reduction in electricity consumption. Smart cities promote energy-efficient gadgets and buildings that lead to less consumption of energy. The social dimension’s positive impacts are increases in satisfaction on life and income level while in the governance dimension, an increase in the number of citizen initiatives. Especially satisfaction on income level and citizen initiatives are statistically significant results.

On the other hand, negative impacts are found in four dimensions except for the economic dimension. In the environmental dimension, CO_2 emission is rather increased in smart cities. It is perhaps related to the increasing number of ICT infrastructure, devices, and networks (Sharma & Park, 2018). In the social dimension, citizen empowerment is lessened for the low-educated population. Smart cities are believed to provide employment opportunities to socially marginalized people (Ménascé et al., 2017), but Korean smart cities are less inclusive for low-educated people. In the governance dimension, the perception of transparency and democracy is decreased in smart cities. Smart cities are thought to be more transparent and democratic governance thanks to open environments (Afzalan et al., 2017; Yigitcanlar, 2015), but citizens feel less transparency and democracy. It can be related to diminishing freedom of speech in smart cities due to personal data collection and the constant feel of surveillance (Hollands, 2008; Vanolo, 2016). Finally, in the technological dimension, perception of information security is reduced in both first- and second-wave smart cities, meaning there are more concerns about privacy violation. Privacy issues are the significant negative impacts of smart cities (Elmaghraby & Losavio, 2014; Galdon-Clavell, 2013; Hollands, 2015). Smart cities in Korea also show people are more concerned about their information security. Another empirical case study on 15 smart cities showed that smart city policies lack bottom-up initiatives and actor engagement while overlooking local characteristics and privacy issues (Angelidou, 2017). It may be caused by the fact that smart city projects mostly focus on application development and installation that shows limited effectiveness (Komninos et al., 2015).

Smart city development provides both benefits and detriment in economic, environmental, social, governance, and technological dimensions. The result showed that the second-wave smart cities perform better than first-wave or non-smart cities in most of the variables. These advanced smart cities are evolved from U-city, not only restricting smart city concepts at a technological level, expanding to “soft” infrastructures such as policies and civil initiatives (Neirotti et al., 2014). It empirically shows the evolution of smart cities, from smart city 1.0 to smart city 2.0 (Trencher, 2019).

6.1.3 What Are the Empirical Impacts of Smart City Development on Environmental Sustainability, Especially the Energy Transition?

The impacts of smart city development identified in the first article showed environmental impacts have relatively fewer empirical studies. In the second article (Chapter 3), the smart cities' impacts on the environment have contradicting indicators that raise the need for an in-depth study on environmental impact. The third article (Chapter 4) provides empirical evidence of smart cities' contribution to environmental sustainability, especially energy transition. Reducing energy consumption and CO2 emission is an essential topic in environmental sustainability in smart cities (Debnath et al., 2014; Snow et al., 2016) and energy transition (Ou, 2018). Energy transition, a systematic change to a low-carbon society (Bridge et al., 2013), can be integrated into smart city planning. This article answers the third sub-research question, which can be specified with the following questions: 1) what is the relationship among environmental sustainability, energy transition, and smart city development; 2) Are smart cities better than non-smart cities in performance of the energy transition? This article hypothesizes that smart cities perform better than non-smart cities in the Smart Energy Transition Index. The categorization of city types (first-wave and second-wave smart cities and non-smart cities) is the same as the second article (Chapter 3).

1) What is the relationship between environmental sustainability, energy transition, and smart city development?

The energy transition is essential to ensure environmental sustainability. It is a systematic change to a low-carbon society (Bridge et al., 2013; Grubler, 2012). The current energy system that is highly reliant on fossil fuel is not sustainable. Therefore, systematic change by holistic urban development is desirable. Cities consume a significant portion of energy and produce GHG (Albino et al., 2015). Simultaneously, cities are the place for innovation and creative solutions to tackle these problems as human and social capital are aggregated (Glaeser, 1994). Especially, ICT and IoT are already in use for energy optimization by collecting energy production, distribution, and consumption data (Talari et al., 2017). Since smart cities' core element is ICT, smart cities can be a shared vision for the energy transition. In academia, there is already an awareness of the need for an integrated smart energy system to ensure environmental sustainability (Leem et al., 2019; Lund, Andersen, Østergaard, Mathiesen, & Connolly, 2012; Mathiesen et al., 2015; Orecchini & Santiangeli, 2011).

However, we do not have a clear understanding of smart cities' contribution to the energy transition. Some argue that smart city development can ensure environmental sustainability by reducing energy consumption and CO2 emission (Debnath et al., 2014; Snow et al., 2016). On the opposite view, there are concerns about smart city development endangering the environment because of the excessive use of ICT (Bibri & Krogstie, 2017; Hollands, 2008). More ICT infrastructures and devices can generate more CO_2 and increase energy demand. In the Chapter 3, South Korean smart cities also showed a somewhat conflicting result on environmental dimension. In smart cities, CO_2 emission was increased, but electricity consumption was decreased while citizen engagement in environmental protection behavior was better.

The hypothesis is that smart cities are contributing to the energy transition. Three core drivers of smart cities are technology, community, and policy (Yigitcanlar et al., 2018). Technological driver contributes with renewable energy and smart grid (Calvillo et al., 2016; Shahrokni et al., 2015). The community can change awareness of people by forming civil initiatives for the energy sector, moderate energy consumption, and facilitate energy-saving behavior. The technological solution is not a panacea; instead, community engagement contributes significantly to the energy transition and smart city development (Corsini et al., 2019). The policy can back up all these changes by supporting research and development (R&D) and setting up rules and regulations for a sustainable energy system (Yigitcanlar et al., 2018).

2) Are smart cities better than non-smart cities in the performance of the energy transition?

Based on the hypothesis, the Smart Energy Transition Index is constructed to measure cities' performance in terms of the energy transition. The index comprises three main drivers of smart cities; technology, community, and policy. Urban characteristics such as population, financial independence rate, GRDP per capita, and urbanized areas are included in the analysis to reflect the cities' inherent smartness. This inherent smartness interacts with the three drivers and generates innovative solutions for urban problems (Neirotti et al., 2014; Wiig, 2015).

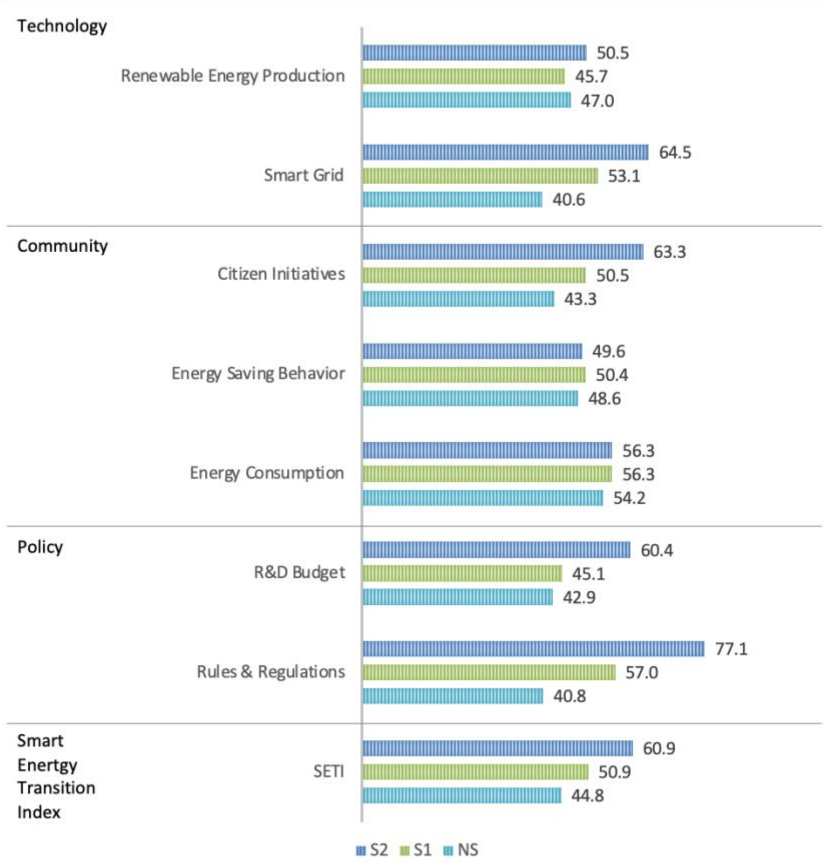


Figure 6.2 Average Score of Indicators and Smart Energy Transition Index
S2: Second-wave smart cities, S1: first-wave smart cities, NS: non-smart cities

Figure 6.2 shows each indicator's average standardized score by city type and average Smart Energy Transition Index. The second-wave smart cities scored highest in renewable energy production, smart grid, citizen initiatives, R&D budget and rules, and regulations. Non-smart city mostly scored the least except in renewable energy production. It is because renewable energy plants are constructed regardless of the smart city development plan. First-wave smart cities scored second to the second-wave smart cities, except for renewable energy production and energy consumption per capita. First- and Second-wave smart cities scored the same in energy consumption per capita. Smart Energy Transition Index score is highest in second-wave smart cities, followed by the first-wave smart cities and non-smart cities.

Table 6.3 summarizes the Smart Energy Transition Index score and average population by city type. The second-wave smart cities scored the highest while the non-smart cities scored the least. Second-wave smart cities have the highest average population, followed by the first-wave smart cities and non-smart cities. Looking at the top and bottom ten cities for Smart Energy Transition Index, the top 10 cities were mostly smart cities. These cities are and metropolitan areas with a large population, well-developed infrastructures, and stable finance. The bottom ten cities were non-smart cities and 'Gun' areas with lower population and financial independence ratio. These descriptive results give a hint at the inherent smartness of the cities.

Table 6.3 Descriptive Results of Smart Energy Transition Index

City Type	Number of cities	Smart Energy Transition Index Score			Average Population
		Mean	Min	Max	
First-wave Smart Cities	42	50.9	33.6	72.8	523,983
Second-wave Smart Cities	12	60.9	46.9	84.0	1,670,548
Non-Smart Cities	107	44.8	27.3	63.9	91,281
Total	161	47.6	27.3	84.0	321,605

Kruskal-Wallis test and Wilcoxon rank-sum test are performed to check whether there is a statistically significant difference among the mean scores. The analysis showed that the second-wave smart cities were significantly different from the first-wave smart cities and non-smart cities. Also, the first-wave smart cities were significantly different from non-smart cities. These results confirm that smart cities can indeed contribute to the smart energy transition. Smart city development focuses on constructing ICT infrastructures and establishing a comprehensive urban management system (L. Anthopoulos, 2017; Zygiaris, 2013). These features enable the energy transition. For smart energy transition, technology, community, policy, and urban characteristics need to be considered. For the technological aspect, mainstreaming renewable energy and smart grids is needed. Communities can engage in energy-saving behaviors and reducing energy consumption as well as forming citizen initiatives. The energy transition is about technological innovation and social and governance innovation (Corsini et al., 2019). End-user behavioral change is critical (Grubler, 2012) as much as managing population density, urban activities, and the urbanization rate, all of which influence overall energy consumption (Creutzig, Baiocchi, Bierkandt, Pichler, & Seto, 2015). That is why the policy also plays an essential role by putting the R&D budget for energy and technology and setting rules and regulations in favor of smart energy transition.

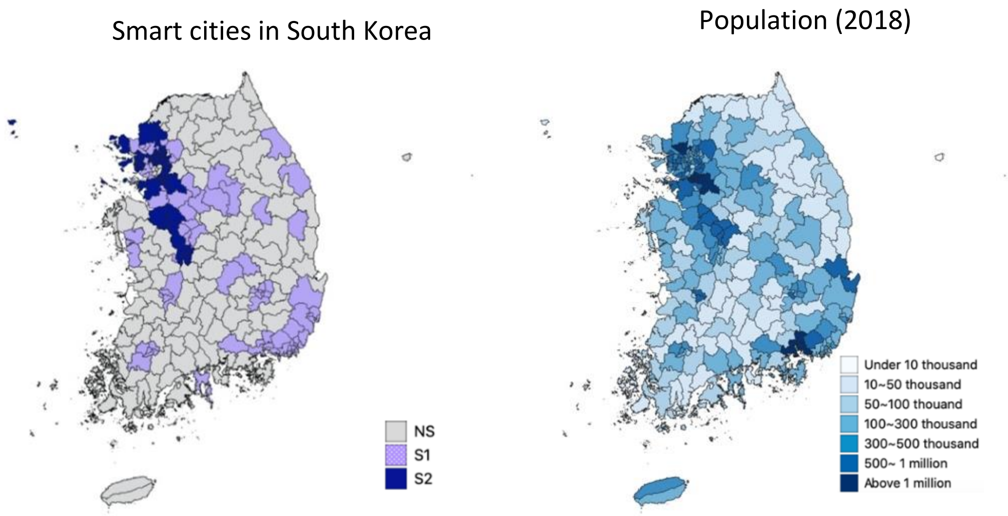


Figure 6.3 Smart Cities and Population in South Korea

First- and second-wave smart cities are highly developed cities, where population and density are high. As shown in Figure 6.3, second-wave smart cities are concentrated in the upper left side, which is Seoul and the metropolitan area. Also, the figure shows an overlap between the high population area and smart cities. A high population means there is a better chance of highly educated and skilled people who can facilitate smart city development by community initiatives. High density eases the implementation of ICT infrastructure. These cities are also equipped with financial stability, where the local governments can use their budget for the projects. This inherent smartness shows each city's potential in adopting smart city development and smart energy transition. The correlation test among Smart Energy Transition Index and these variables showed positive relationships, except for GRDP per capita. Here, a few urban characteristics were considered, but intangible assets such as human and social capital can also be accountable as inherent smartness (Caragliu & Del Bo, 2018).

According to Nielsen et al. (2013, p.3), a smart energy city equates to a city with greater energy efficiency through the use of ICT and the promotion of renewable energy to provide a sustainable living environment. Parallel to this definition, Mosannenzadeh, Nucci, and Vettorate (2017) provided a holistic definition of a smart energy city as "a component of smart city development aiming at a site-specific continuous transition towards sustainability, self-sufficiency, and resilience of energy systems, while ensuring accessibility, affordability, and adequacy of energy services, through optimized integration of energy conservation, energy efficiency, and local renewable energy sources (p.57)." Like these definitions, the energy transition can be integrated into smart city development.

6.1.4 What Are the Empirical Impacts of Smart City Development on Governance?

As well as a lack of evidence on environmental sustainability, smart city discourses have less attention to the empirical studies on governance (De Jong et al., 2015; Meijer & Bolívar, 2016). The last article (Chapter 5) looks into the process of developing smart cities through the lens of governance. Governance is an essential topic because various stakeholders are involved, and their relationship influences smart cities' development (Leydesdorff & Deakin, 2011). This article reveals the changing facade of governance models in developing smart cities by studying three smart cities in South Korea, Seoul, Songdo (Incheon), and Sejong. A framework is developed to identify the governance model. The research question is divided into three: 1) how do we identify the governance model empirically; 2) how does the governance model change in different phases of smart city development; and 3) what is the appropriate governance model for developing smart cities?

1) How do we identify the governance model empirically?

There are many ways to define governance models. Pierre (1999) distinguished four types of governance: managerial, corporatist, pro-growth, and welfare governance by the difference in participants, objectives, instruments, and outcomes. Managerial governance emphasizes the government as a provider of public services. It adopts the private sector's management scheme, such as incentives or competition in the public sector that became fashionable with neoliberalism (Rhodes, 1996). Corporatist governance emphasizes negotiation, collaboration, and civic engagement. The process takes longer, but the implementation can be easier. Pro-growth governance focuses on local economic development, led by public and private interaction. Because economic growth is the main force of this model, there is little room for participation; instead, the public and private elites decide the best strategy for local economic growth. Finally, welfare governance seriously takes up the government's role, which depends highly on the central government's spending.

Building upon Pierre's governance models, Klijn and Koppenjan (2015) suggested four governance models (corporate, market, multi-level, and collaborative) by the government's role. They added multi-level governance, focusing on the relationship among different levels in public agencies (Hooghe & Marks, 2003). This article adopts Klijn and Koppenjan's governance models since their model shows the evolution of the governance model. They put the network (collaborative) governance model as an ideal and authentic governance model.

Collaborative governance is also emphasized in smart city literature (e.g., Jang & Kim, 2017; Lopes, 2017). A systematic literature review regarding smart city governance presents smart urban collaboration as a high level of transformation that focuses on innovative governance networks (Meijer & Bolívar, 2016). Smart cities pursue citizen engagement and participatory decision-making processes (Afzalan et al., 2017; Caragliu et al., 2009; Kitchin, 2014). Therefore, smart city governance is about creating collaboration among stakeholders through utilizing ICT for more transparent and democratic processes (Meijer & Bolívar, 2016).

Although collaborative governance is the ideal and goal of smart city governance, the process of smart city development may have different forms of governance. The last article pays attention to different phases of smart city development and their governance model. Each governance model can be settled by investigating the role of actors and interaction mode. The participants are the actors or stakeholders, including the public (government agencies), private (firms, enterprises, market, industry), academic (knowledge institutes and university), and civic (citizens, community, NGOs) (Ruhlandt, 2018). The modes of the relationship among these participants are participation, partnership, and collaboration.

In corporate governance, the government takes the role of a ruler. The government sets the laws and rules while the non-public actors act as participants. In market governance (concession model PPP), the government is the commissioner, and the other actors are executers. Here, usually, private actors are the executer by the contract, while civil and academic actors are participants. Multi-level governance focuses on the relationship between different levels of governmental agencies. The central government takes the commissioner or facilitator's role while the local government becomes executer or partner. Their interaction mode is partnership. Finally, collaborative governance is a desirable governance model in smart cities. It includes the partnership model PPP and collaborative governance. In partnership PPP, the government is a coproducer while the other actors are partners. In collaborative governance, the government is a facilitator, and the other actors are initiators.

The governance model is analyzed by identifying the actors and their roles from policy documents such as smart city master plans and law and ordinances. The analysis is then expanded to secondary data such as news articles, reports from knowledge institutes, and academic papers. The news articles are gathered from a digital archive with a keyword search (smart city or ubiquitous city). Three smart cities are selected, Seoul, Songdo (Incheon), and Sejong.

2) How does the governance model change in different phases of smart city development?

South Korean smart city development has three phases:

1. The first phase (2008-2013): the initiation period
2. The second phase (2014-2018): the expending period
3. The third phase (2019-2023): the maturing period

Each phase has different smart city visions, characteristics, and focuses. The three smart cities are Seoul, Songdo (Incheon), and Sejong, referred to as representative smart cities in Korea. Seoul and Songdo are second-wave smart cities which scored high in the Smart City Impact Index and Smart Energy Transition Index in the second and third article. Sejong was excluded in these analyses due to a lack of statistical data before 2012. However, this paper includes Sejong, one of the nationally promoted smart cities since 2018.

Table 6.4 summarizes governance models in each phase of three smart cities. First, Seoul showed market governance in the first and second phases.

Then it changed to partnership PPP, premature collaborative governance in the last phase. Songdo had turbulence in smart city projects due to political and economic influence. It initially started with partnership PPP, but in the second phase, it moved to market governance. The private partner had to pull out their finance due to the global economic crisis, and the government took the leading role. In the third phase, the governance model became back to partnership PPP. The governance model in the first and second phases in Sejong is multi-level governance. Many governmental agencies were involved in making Sejong, which is designated as Multifunctional Administrative City by the central government. Public actors include NAACC (central government), who was in charge of developing Multifunctional Administrative City, Sejong municipality, and Korea Land and Housing Corporation (LH). Private, civil, and academic actors involved as participants. In the third phase, as the government acknowledged the importance of involving other actors, the governance model changed to collaborative governance.

Table 6.4 Governance Models in Seoul, Songdo, and Sejong

City	Governance Model		
	Phase 1	Phase 2	Phase 3
Seoul	Market	Market	Partnership PPP (Collaborative)
Songdo (Incheon)	Partnership PPP (Collaborative)	Market	Partnership PPP (Collaborative)
Sejong	Multi-level	Multi-level	Collaborative

All three cities showed a gradual change to collaborative governance. They tried to involve more actors in the decision-making process. Especially, citizen engagement is highlighted. Seoul established a smart city initiative that includes public, private partners, and citizens. Songdo focused on developing user-centric smart services. Furthermore, Sejong initiated Smart Living Lab that involves citizens also.

On the other hand, there was conflict among actors due to unclear roles and responsibilities. Especially in Sejong, NAACC and Sejong municipality had conflict over ownership of the Smart City Master Plan. It was due to dual authority because NAACC used to be in charge of administrative matters before the Sejong municipality was officially set up in 2012. However, even after the Sejong municipality was initiated, NAACC is still in charge of urban development in Sejong because Sejong is designated as Special Multifunctional Administrative City by the national government. To solve this problem, NAACC, Sejong municipality, and LH agreed to work together for Sejong smart city development. Unclear responsibility is one of the major concerns on the effectiveness of collaborative governance (Benner et al., 2004). Collaborative governance is desirable; however, unclear roles can result in conflict in ownership over the project that delays the development process. However, it can be overcome by discussion among stakeholders to define responsibilities and roles.

3) What is the appropriate governance model for developing smart cities?

The governance model shows changes in different phases of smart city development. The South Korean example shows three phases in smart city development. The first phase focuses on constructing ICT infrastructures. Once the basic infrastructure is established, the second phase provides smart services. Finally, in the third phase, the overall urban system adapts to the smart system, and the impacts reach citizens. In each phase, the governance model changes. In the first phase, market governance can be useful because strong leadership can accelerate the process. In more maturing phases, more actors need to be involved in the decision-making process.

South Korean experience showed three phases in smart city development and governance model. This tendency can also be found in other cities such as Amsterdam, Barcelona, Lisbon, and Vienna (Camboim, Zawislak, & Pufal, 2019). The first phase is smart strategies, building ICT infrastructures by the leading of the advanced governance model. The second phase is smart projects, bringing more complicated changes in socio-institutional, techno-economy, and environment-urban. Finally, the third phase is smart performance, the previous two steps' results, achieving sustainable socio-economic development.

Table 6.5 summarizes the characteristics of governance in each phase found in the South Korean case study and four European cities. South Korean experience and other cities show smart cities are evolving from smart city 1.0 to smart city 2.0 (Trencher, 2019), and even to smart city 3.0. Smart cities 1.0, the first-wave smart cities in the Korean case, or smart strategies in Amsterdam, Barcelona, Lisbon, and Vienna focus on ICT appliance and technological diffusion. It is making the foundation for smart cities by constructing infrastructures and setting up basic smart services in urban sectors such as transport or energy. Smart cities 2.0, the second-wave smart cities in the Korean case and smart projects in four European cities, are more matured smart cities, where the impact of smart city development is slowly bringing to fruition in economic, social, environmental, and governance dimensions. Here, some negative impacts can be posed, such as inequality or privacy issues. It brings the needs for collaborative governance especially, citizen engagement, because citizens are the end-users of smart cities. Smart cities 3.0 is the smart performance of four European cities and the third phase of smart city planning in Korea, where smart city development results are visible. Mature smart cities bring broader positive changes to the city, such as high quality of life and sustainable development.

Table 6.5 Evolution of Smart Cities

Smart City	Smart City 1.0	Smart City 2.0	Smart City
Phase	Initial Phase	Maturing Phase	Completion Phase
Korean Case	First-wave Smart Cities (U-cities)	Second-wave Smart Cities	Smart cities
Four European Cities*	Smart Strategies	Smart Projects	Smart Performance
Governance Model	Market (Concession PPP)	Partnership PPP (Collaborative)	Collaborative
Role of Government	Commissioner	Coproducer/Facilitator	Facilitator

* Four European cities are from the work of Camboim, Zawislak and Pufal (2019).

Current smart cities are criticized for lack of collaboration and engagement from various stakeholders (Kitchin, 2015). Therefore, collaborative governance is desirable for future smart city development (Klijn & Koppenjan, 2015). However, when autonomous collaboration is hard to form due to planning culture, a state-guided collaboration can be an alternative. Some smart city projects already show a form of state-guided collaboration. For example, Barcelona started their smart city project with public funding for infrastructure. Later on, tax and land use incentives were given to encourage private investment (Camboim et al., 2019). The initial phase of smart city development is infrastructure construction that needs public investment. The state-guided collaboration puts the government in a focal role carrying out smart city development until the end with stable financial and political support. The government can play the "dedicated organization" role (Camboim et al., 2019). Once the smart city infrastructures are in place, private, citizen, and academic groups collaborate to create more mature smart cities. The public agencies can provide incentives to encourage private investment like in Barcelona and Songdo while creating an open environment where actors can exchange opinions and collaborate.

6.1.5 What are the impacts of smart city development on urban sustainability?

Smart cities, in general, are expected to achieve sustainable urban development. Especially, smart cities promise to increase economic productivity, reduce administrative costs of public services, and provide a more pleasant living environment (Caragliu, Del Bo, & Nijkamp, 2011; Neirotti et al., 2014; Zanella et al., 2014). The empirical study on South Korea suggests that smart city development has both positive and negative impacts. The positive impacts are observed in all dimensions of sustainability and technology. Performances in income level, energy consumption, quality of life, citizen engagement, and innovation were enhanced in smart cities. On the other hand, some negative impacts were also observed. Smart cities were worse in CO_2 emission in the industrial sector, equality, transparency and democracy, as well as privacy issue.

On remark of environmental dimension, more CO2 emission in smart cities is somewhat conflicting to the result of Chapter 3, where smart cities performed better in energy transition (environmental sustainability). Due to the limited dataset, CO_2 emission data only considered industrial sectors mostly concentrated in urban areas where smart city development is on-going. Apart from that, smart cities can be more sustainable than non-smart cities with investment in renewable energy production and smart grid, more citizen engagement, and political support.

It is also worth noting that non-smart cities performed better in some social indicators, especially citizen empowerment (employment of low-educated and elderly). It can lead to further inequality. Smart cities initially thought to provide more job opportunities to socially marginalized groups, but it was not true in the Korean case. Florida points out that creative cities are unequal to normal or less developed cities (e.g., collapse of the middle-class) (Florida, 2017). Like creative cities, South Korean smart cities are more developed cities. This observation is a good reminder that urbanization is not neutral. It needs strict attention for inclusiveness and equality.

It also goes the same with South Korean smart cities, which showed both positive and negative impacts. Smart city development needs carefully constructed intervention. Current smart city projects are highly pro-commercial and pro-technology, which sometimes neglect the purpose of urban planning. Smart city development can be a compelling vision for the leaders because it promises visible outcomes. However, it can also divert policy priority from urgent urban problems such as poverty and unemployment (Afzalan et al., 2017; Hollands, 2015; McNeill, 2015). In effect, the Chinese and Indian governments strive to develop smart cities, but critics argue they are neglecting urban poor, housing deficit, and high unemployment rate issues (Datta, 2015a; Söderström et al., 2014). Smart cities need to be more than mere marketing schemes of international ICT vendors (Hollands, 2008; Söderström et al., 2014). Careful consideration of human, social, and institutional capital and technology can facilitate social development (just and equal society) in smart cities.

South Korean experience shows how the government can regulate and supervise smart city projects. The government can restrict the intention of private corporates that can sometimes be opposing to the public interest. At the same time, top-down and pre-made strategies can enhance efficiency in project implementation. However, as critics point out, the top-down approach is rigid that can hinder a variety of urban solutions. Bottom-up and citizen-initiated projects may not be directly related to smart technology, but they can identify the city's real problems and come up with innovative solutions. Public, private, academic, and civil initiatives need to work together for desirable results of smart city development (Yigitcanlar et al., 2018).

6.2 Implication

Cities are evolving into smart cities, facilitating socio-economic development while reducing the environmental impact by using the technologies (Dirks & Keeling, 2009; Hall et al., 2000; Harrison & Donnelly, 2011; Toppeta, 2010; Washburn et al., 2009; Zygiaris, 2013). This thesis studies the impacts of smart city development on urban sustainability and delivers some implications.

The first implication is it provides an overall map for hypothetical and observed positive and negative impacts of smart city development. Smart cities brought aspiration among decision-makers and businesses due to their novelty and attractiveness. However, there was little understanding of what smart city development brings to the city. The first article identifies 12 positive and four negative impacts. It also provides which impacts are observed with empirical evidence. It can serve as guidance for policy-makers considering both the positive and negative impacts of smart city development. Naturally, positive impacts received more attention than negative impacts because it promises attractive results such as economic development, efficiency, and high quality of life. However, more attention is needed to the negative impacts on inequality, existing urban problems, freedom of speech, and privacy.

The second implication is it provides various evaluation tools for smart city impacts and governance. Two indices are developed to measure the performance of smart cities in terms of sustainability and energy transition. The first index, the Smart City Impact Index, encompasses both positive and negative impacts in four sustainability dimensions (economy, environment, social, and governance) and technology dimensions. The ten variables and 17 indicators are presented and tested with South Korean smart and non-smart cities. The second index, the Smart Energy Transition Index, is constructed with three smart city drivers (technology, community, and policy) and urban characteristics that reflect the inherent urban smartness. The Smart Energy Transition Index consists of 13 indicators. Finally, a framework is developed to identify the governance models in different stages of smart city development. Four major governance models (corporate, market, multilevel, and collaborative) are identified from the literature review. The actors' role and interaction mode are presented as identification criteria. Other cities and countries can adopt these evaluation tools. Specific indicators may vary due to the availability of data, but the framework can be used universally.

The third implication is that it provides empirical evidence on the performance of smart cities in urban sustainability. The first article (Chapter 2) identified six positive and two negative impacts without any empirical evidence. The second article (Chapter 3) tried to reveal observed positive and negative impacts to fill in this research gap. Among hypothesized positive impacts, citizen involvement, protecting the environment, facilitating social development and social capital, and fostering innovation showed evidence. Two negative impacts, privacy issues and diminishing democracy, also showed empirical evidence. Citizen initiative, an indicator of citizen involvement, showed an increase in smart cities. Also, the score for online participation was high in smart cities than in non-smart cities.

The fourth implication is that the research goes further to explain the environmental and governance impacts of smart cities, which are often neglected in current smart city literature. Environmental sustainability is represented as the energy transition because the current energy system is not sustainable and needs systematic change. Achieving energy transition shares commonalities with smart city development, such as technological solutions and comprehensive change in the urban system. In the third article (Chapter 4), the framework of the smart city's contribution to energy transition is presented and backed up with empirical analysis using the Smart Energy Transition Index. Since climate change threatens urban life, it is crucial to think comprehensively. Smart city development can be one solution because smart cities pursue comprehensive urban development and management.

The final implication is that this thesis suggests governance models suitable for different phases of smart city development. Smart cities promote collaborative governance, but sometimes collaboration is difficult to form due to culture and customs. A state-guided collaboration can be an alternative in such circumstances. The government takes the facilitating role, carries out the projects, and encourages other stakeholders to participate and engage in the decision-making process.

6.3 Limitations and Future Research Agenda

6.3.1 Limitations

There are several limitations of this thesis. The first article (Chapter 2) uses a systematic literature review and only considered peer-reviewed articles and full articles in conference papers. There can be observed impacts in other literature. Also, the review only considered articles in urban planning fields. Computer science and engineering fields also study smart cities, and their results may have observed impacts.

Another limitation is that the researches used imperfect datasets due to unavailability. In the second and third articles (Chapter 3 and 4), some indicators used provincial data instead of city-level data due to unavailability. This results in imperfect datasets that may influence analyzing the phenomenon accurately. Also, in the fourth article (Chapter 5), only secondary data are used. Other methods such as interviews or surveys could provide more detailed information on the governance of smart cities.

Also, the way of defining smart cities for the South Korean case study is another limitation. South Korean smart cities are defined as the cities where the government initiates smart city projects. The governments initiate many smart cities, but there can be citizen-led smart city projects. They may have different approaches and results compared to state-initiated smart cities.

Finally, the geographical scope is limited to South Korea. South Korea is an interesting case because smart city development is promoted as a national development strategy from the early stage, but smart cities are developed worldwide. Other countries with different cultures and backgrounds have different motives and strategies to develop smart cities and yield different results.

6.3.2 Future Research Agenda

Based on these limitations, the recommendations for future research are as follows. First, in-depth empirical studies are needed to further examine the positive and negative impacts of smart city development. The first article identified 12 positive and four negative impacts. Among them, six positive and two negative impacts are yet backed up by empirical evidence. In the second article, those impacts were found but macro-level with numbers and statistics. In-depth case studies can provide which impacts are observed in what condition. Further researches can focus on what kinds of urban characteristics (e.g., demography, economic and political situation, human and social capacities) foster or hinder positive and negative impacts.

Second, we need more studies focusing on the difference among countries in smart city development. The South Korean case shows valuable lessons for developed countries. However, it can be expanded to other countries, including developing countries. As the first article showed, less attention is given to middle- and low-income countries in developing smart cities. Also, since smart cities are advocated much by high-income countries, the empirical impacts can be different by countries. In-depth researches can bring more contextual factors into account.

Third, future research can focus on citizens' views. The articles in this thesis focused on city-level impacts rather than individual-level. Since the citizens are the end-user of smart cities, their opinions matter. It is interesting to see how citizens feel about smart cities, either positive or negative.

Fourth, in addition to the focus on citizens, more studies are needed for citizen-initiated smart cities. South Korean cases are mostly government-initiated smart city projects that are promoted as a national development strategy. Citizen-initiated smart city projects can have different strategies and goals that can lead to different results.

Finally, there is a need for in-depth studies on the relationship between the governance model and the impacts of smart city development. Different governance models are chosen based on the planning culture and urban characteristics. It may influence realizing the impacts. Further research is needed to reveal the governance model that enhances positive impacts while avoiding the negative ones.

6.4 Policy Recommendation

Smart city development is expected to contribute to urban sustainability (Yigitcanlar et al., 2018). This final section provides valuable policy recommendations to policymakers for successful smart city development.

First, smart city development requires different approaches because cities have different capacities on the technological level, degree of collaboration, planning practice, human resources, and institutional capital (Meijer & Bolívar, 2016). Implementing smart cities depends on a city's political and socio-economic environment, thereby making each city unique (Mosannenzadeh & Vettorato, 2014). It is confirmed when we skim through current smart city development around the world. Amsterdam branded themselves as 'Urban Living Lab' where businesses, government agencies, research institutes, and citizens collaborate to test new technologies and services (Meijer & Bolívar, 2016). City of Philadelphia adopted '311 non-emergency response system,' which brought innovative urban governance (Nam & Pardo, 2014). South Korea appointed smart city development as a national economic development strategy in 2017, while India's prime minister announced an ambitious plan to build 100 smart cities in India, mainly as urban renewal and retrofitting strategy in 2015. Each country or city has different intentions and goals to develop smart cities. Therefore, a clear vision and goals need to be established.

Second, encouraging the participation of various stakeholders is essential in making smart cities. The major driving force of smart city development is ICT, provided by global ICT vendors including IBM, CISCO, and Google (Dameri et al., 2018). Since private corporations prioritize maximum revenue, it is cost-effective to develop a standardized solution and sell it to local governments. This happens in many other cities, just adopting what other cities are doing without considering different social and urban characteristics (Mattoni, Gugliermetti, & Bisegna, 2015). However, cities have different capacities (Meijer & Bolívar, 2016); therefore, bringing various local stakeholders to the decision-making table is essential. The stakeholders are not mere participants of the projects. They also share the responsibilities of smart city development (Ansell & Gash, 2008). Public, private, academic, and civil initiatives need to work together for desirable results of smart city development (Snow et al., 2016; Yigitcanlar et al., 2018). To encourage community participation, planning and decision-making processes need to be democratic and collaborative (Snow et al., 2016). Public, private, civil, and academic actors can collaborate under the shared vision of the smart city.

Third, more attention is needed for citizens. Current smart city planning often overlooks citizens' perspectives (Engelbert, van Zoonen, & Hirzalla, 2019). Citizen-centric governance is vital to ensure the quality of life of citizens. Because at the end of the day, citizens are the end-user of the city. This also leads to citizen empowerment. It is challenging to draw citizen participation when there is a lack of trust and transparency (Corsini et al., 2019). To avoid this, ICT can contribute to establishing an open data environment where anyone can access public data. Bottom-up and citizen-initiated projects may not be directly related to smart technology. However, they can identify the city's real problems and come up with innovative solutions (although they are not advanced technology). For example, Amsterdam smart city provides a platform to find private-public or private-citizen partnerships for local projects. Focusing on citizens lead to considering the sub-context of smart city development, including demographic characteristics, planning and political culture, and challenges the city is facing (Fernandez-Anez et al., 2018). Besides, since not all citizens can freely use digital devices, especially elderlies or the poor, citizen empowerment is essential. The digital divide can enlarge the gap and inequality in employment, housing, and neighborhoods (Hollands, 2008). Therefore, a more inclusive and citizen-centric approach is needed.

Fourth, smart cities need national or even international level policies (Contreras & Platania, 2019). Although governance is a shift from 'command and control' state (Peters & Pierre, 2011), the government still plays a focal role because their policy influences public, private, or civic entities' engagement in solving urban problems and arrangement of public goods and services (Weiss, 2000). A national-level policy can provide this atmosphere by improving regulations for innovation. For example, there are temporary waivers for businesses in Korea specializing in new technology (e.g., autonomous vehicles, drones, and renewable energy). The Korean government introduced 'Smart City-type Regulatory Sandbox' to alleviate regulations that may hinder smart city projects.

Fifth, smart cities can be both an opportunity and a crisis for middle- to low-income countries. E-government can contribute to tackling corruption because open public information creates a transparent environment (Afzalan et al., 2017). On the other hand, the execution is challenging due to rooted national and urban problems in developing countries. Developing countries focus on smart city readiness (Noori, de Jong, & Hoppe, 2020). The lack of financial, institutional, and technological capacities is a major challenge (Tan & Taeihagh, 2020; Vu & Hartley, 2018). Institutional capacity is significant because smart city development needs a clear and sound execution strategy (Vu & Hartley, 2018). Smart cities require vast financial and technological investments. Without a clear strategy, those investments can be wasted, which would have been used for other issues like poverty, housing, and unemployment (Datta, 2015a; Söderström et al., 2014). Smart cities seem to be a panacea for urban problems, but the leadership needs specific goals, master and execution plans, and appropriate regulations.

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A. Additional Data for Chapter 2

This appendix provides additional data for Chapter 2. Table A.1 shows the code and information on 55 selected articles for a systematic literature review. Table A.2 is the list of quotations of smart city definitions that are found in the selected articles.

Table A.1 List of Selected Articles and Codes

Code	Title	Author	Year
1	(Not so) smart cities?: The drivers, impact and risks of surveillance-enabled smart environments	Galdon-Clavell	2013
2	A methodological framework for benchmarking smart transport cities	Debnath et al.	2014
3	A Smart City Initiative: The Case of Barcelona	Bakici, Almirall, & Wareham	2013
4	A Smart City Is a Collaborative Community: LESSONS FROM SMART AARHUS	Snow et al.	2016
5	Anticipatory logics of the smart city's global imaginary	White	2016
6	Are smart card ticketing systems profitable? Evidence from the city of Trondheim	Welde	2012
7	Civic entrepreneurial ecosystems: Smart city emergence in Kansas City	Sarma & Sunny	2017
8	Co-Governing Smart Cities through Living Labs. Top Evidences from EU	Bifulco et al.	2017
9	Conceptualizing smartness in government: An integrative and multi-dimensional view	Gil-Garcia, Zhang, & Puron-Cid	2016
10	Creating smarter cities: Considerations for selecting online participatory tools	Afzalan et al.	2017
11	Critical interventions into the corporate smart city	Hollands	2015
12	Current trends in Smart City initiatives: Some stylised facts	Neirotti et al.	2014
13	Cyber security challenges in smart cities: Safety, security and privacy	Elmaghraby & Losavio	2014
14	Datafied and Divided: Techno-Dimensions of Inequality in American Cities	Brannon	2017
15	Digital infrastructures and Urban governance	Barns, et al.	2017
16	European plans for the smart city: from theories and rules to logistics test case	Russo, et al.	2016
17	Global firms and smart technologies: IBM and the reduction of cities	McNeill	2015

18	How to strategize smart cities: Revealing the SMART model	Ben Letaifa	2015
19	Human Limitations to Introduction of Smart Cities: Comparative Analysis from Two CEE Cities	Klimovsky et al.	2016
20	IBM's smart city as techno-utopian policy mobility	Wiig	2015
21	IBM-building sustainable cities through partnerships and integrated approaches	Sajhau	2017
22	Innovating and Exploiting Entrepreneurial Opportunities in Smart Cities: Evidence from Germany	Kraus et al.	2015
23	Is there anybody out there? The place and role of citizens in tomorrow's smart cities	Vanolo	2016
24	Knowledge and intellectual capital in smart city	Dameri, Ricciardi & D'Auria	2014
25	New urban utopias of postcolonial India: 'Entrepreneurial urbanization' in Dholera smart city, Gujarat	Datta	2015
26	On alternative smart cities: From a technology-intensive to a knowledge-intensive smart urbanism	McFarlane & Soderstrom	2017
27	Shaking for innovation: The (re)building of a (smart) city in a post disaster environment	Marek, Campbell, & Bui	2017
28	Shortcomings to Smart City Planning and Development Exploring Patterns and Relationships	Angelidou	2017
29	Smart cities and new forms of employment	Ménascé, Vincent, & Moreau	2017
30	Smart cities as corporate storytelling	Soderstrom, Paasche & Klauser	2014
31	Smart cities in Europe	Caragliu, del Bo & Nijkamp	2011
32	Smart cities: A conjuncture of four forces	Angelidou	2015
33	Smart cities: an effective urban development and management model?	Yigitcanlar	2015
34	Smart cities: Utopia or neoliberal ideology?	Grossi & Pianezzi	2017
35	Smart city intellectual capital: an emerging view of territorial systems innovation management	Dameri & Ricciardi	2015
36	Smart city or smart citizens? The Barcelona case	Capdevila & Zarlenga	2015
37	Smart City Reference Model: Assisting Planners to Conceptualize the Building of Smart City Innovation Ecosystems	Zygiaris	2013

38	Smart utopia VS smart reality: Learning by experience from 10 smart city cases	Anthopoulos	2017
39	Special Issue on Smart Cities and the Future Internet in Europe	Komninos, Pallot & Schaffers	2013
40	The "Sustainable'' in smart cities: ignoring the importance of urban ecosystems	Mundoli, Unnikrishnan & Nagendra	2017
41	The changing face of a city government: A case study of Philly311	Nam & Pardo	2014
42	The digital skin of cities: Urban theory and research in the age of the sensored and metered city, ubiquitous computing and big data	Rabari & Storper	2015
43	The effect of ICT use and capability on knowledge-based cities	Navarro, Ruiz, & Pena	2017
44	The effects of successful ICT-based smart city services: From citizens' perspectives	Yeh	2017
45	The empty rhetoric of the smart city: from digital inclusion to economic promotion in Philadelphia	Wiig	2016
46	The Operationalizing Aspects of Smart Cities: the Case of Turkeys Smart Strategies	Bilbil	2017
47	The real-time city? Big data and smart urbanism	Kitchin	2014
48	The Role of Smart City Characteristics in the Plans of Fifteen Cities	Angelidou	2017
49	The Smart City as an opportunity for entrepreneurship	Richter, Kraus & Syrja	2015
50	Toward Intelligent Thessaloniki: From an Agglomeration of Apps to Smart Districts	Komninos & Tsarchopoulos	2013
51	Towards an effective framework for building smart cities: Lessons from Seoul and San Francisco	Lee, Hancock & Hu	2014
52	Urban smartness and sustainability in Europe. An ex ante assessment of environmental, social and cultural domains	Manitiu & Pedrini	2016
53	Will the real smart city please stand up? Intelligent, progressive or entrepreneurial?	Hollands	2008
54	'Smart Growth': Increasing the smartness of cities through smart healthcare solutions	Toraldo, M. L., & Mangia, G.	2013
55	E-City councils within Italian smart cities	Romanelli	2013

Table A.2 List of Definitions

Code	Definition (page)
2	• In general, a smart city is characterized by its ICT infrastructures, facilitating an urban system which is increasingly smart, inter-connected, and sustainable.

	(48)
3	• A Smart City should be able to actively generate smart ideas in an open environment through fostering clusters of Open Data or developing proper living labs while directly involving citizens in the co-creation process of products or services. (136) • For Barcelona, smart city implies a high-tech intensive and an advanced city that connects people, information and city elements using new technologies in order to create a sustainable, greener city, competitive and innovative commerce and a recuperating life quality with a straightforward administration and a good maintenance system
4	• A "Smart" city uses digital technologies to enhance performance and well-being, reduce costs and resource consumption, and engage more effectively and actively with its citizens. […] Cities can only become smarter by fostering greater collaboration among policymakers, companies, entrepreneurs, and citizens. (92-3) • We believe Aarhus, Denmark, is becoming a smart city because it uses a collaborative model of development and because it is trying to be smart in both the technological and social realms. (107)
5	• Smart city breaks the crisis into a broad set of smaller anticipated challenges which can then be addressed by pre-emptive action. [...] the smart city seeks to prepare for mass urbanization by pre-empting its anticipated effects on infrastructure and resource management. (580)
7	• For our study, we adopt the definition of smart city as a conceptual urban development model that underscores the utilization of human, social, and technological capital for the development of regions. (844)
8	• Smart cities aim at solving critical issues within urban areas, such as public services unavailability or shortages, traffic, over-development, environmental shortcomings, and other forms of inequality, all through ICT-based technology that is connected up as an urban infrastructure. (22)
9	• A smart city is ICT-enabled public sector innovation made in urban settings. (526)
10	• We argue that smart-city approaches should contribute to innovation and enhance democratic decision making and transparency through public participation. Participatory process play crucial roles in creating smarter cities by helping organizations respond to wicked problems, democratize decision making, learning about citizens' interests and ideas, or increase social capital. (22)
11	• A smart city is made up of IT devices, industry and business, governance and urban services, neighborhoods, housing and people, education, buildings, lifestyle, transport and the environment. Because it is made up of such a diverse range of things, the smart city idea can inadvertently bring together different aspects of urban life that do not necessarily belong together, hiding some things and bringing others to the ideological fore. (64) • All of these examples exemplify not just a 'right to use technology', which is precisely where many smart city initiatives stop, but rather the right to shape

	the city using human initiative and technology for social purposes to make our cities better and more sustainable. (72)
12	• There is wide agreement about the fact that SCs are characterized by a pervasive use of Information and Communication Technologies (ICT), which, in various urban domains, help cities make better use of their resources. (25)
16	• Considering current advances in technologies, design and social relationships, smart city is one of the possible paradigms for the future of the city. (1713)
18	• Smart cities are hybrid models combining democratized open innovation with central city support, coordination, and monitoring. […] This study posits that smart cities differ from intelligent and creative cities by offering a balanced centricity among technology, institutions, and people. (1415)
19	• Smart cities are defined in terms of the outcomes of the smart city concept: smart cities are more efficient, sustainable and pleasanter to live in. (81) • The use of ICTs is a core feature of the smart city concept. (81-2) • The smart city concept implies that a city has the ambition of improving its economic, social and environmental standards, and consequently also its competitiveness compared to other cities. (82) • Smart cities can be understood as enabling individuals to indicate which of their needs are not met, to report their needs and to have a reasonable expectation that local authorities will help them satisfy their needs. (83) • Smart cities as a social manifestation of the technical development of urban areas would mainly influence two different types of human needs according to the Maslow hierarchy: security and self-actualization. (84)
20	• The smart city can therefore be defined as the clever balance to be found between technology, as the basis, and the ambitious goal of sustainable development and improved urban living conditions. (53)
21	• A core assumption of the smart city is techno-utopian […]. (259-60) • The smart city was an empty rhetorical device able to be filled with any number of comparable or conflicting definitions, since all cities want to be smart, or at least to appear not 'dumb.' (271)
22	• Smart cities are agglomerated areas of high concentrations of learning and innovation. In such areas creativity, innovation and entrepreneurship, coupled with digital infrastructure, aim to drive economic growth and a better quality of life. (602) • Social and environmental sustainability is crucial for smart cities in times of gaining wealth from increasing urban tourism and natural resources. (604)
26	• A redefined SU (smart urbanism) should be grounded in places -actually existing cities – with their specific populations, resources and problems, rather than start with technology. (313) • Alternative SU needs to begin with ordinary urban places, knowledges and needs […] technological solutions should, when needed, be shaped by place-relevant forms of knowledge. (313) • Critical notion of smart must be rooted in the urban context, in the knowledge generated through the needs, desires and realities of ordinary lives, especially marginal groups so often at the margins of urban planning. (318)

	• Alternative SU can be generated through foregrounding smart in the life, worlds of different marginalized groups in the city […] a place-based, experiential and largely neglected urban knowledges of residents in precarious contexts. (324) • Instead of technology-push strategies of urban management, a knowledge-intensive SU should strive to shape technology to put it in the service of social improvement. (325)
27	• We define "smart cities" as cities in which ubiquitous sensors and devices allow for more efficient processes of city management, smoother flow of information systems, and/or optimized use of infrastructure. (41) • A city, which is livable for its citizens, sustainable to its environment, and resilient to (natural and artificial) threats. A city where smart technologies drive effective governance through the engagement of citizens, optimize the flows in the city in real time, where smart(er) citizens create innovative environment and business opportunities by sharing knowledge and information. (49) • Today's smart cities must focus on how the immediate concerns of citizens can become a part of a smarter city in the long term – economically, socially, technologically, and otherwise. (49)
30	• The smarter cities (IBM) model does not suggest a revolution in urban morphology […], but a reformist optimization through data, monitoring, interconnectedness and automatic steering mechanisms. (316)
31	• We believe a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance. (50)
32	• What is certain, though, is that smart cities represent a multidisciplinary field, constantly shaped by advancements in technology and urban development. (95) • Smart cities are also based on an entire type of visioning and thinking about technology-led urban development which continues to influence current urban development policies and priorities on a global scale. Contrary to what many believe, a cohesive smart city strategy must capitalize both on technology (i.e. digital intelligence) and on knowledge (i.e. human intelligence) to achieve spatial development. (104)
34	• The concept of concrete utopia has been used to define the smart city initiatives: the advocates of this paradigm (public, private, and not-for profit actors) describe the smart city as a "concrete utopia in an urban space at human scale" • Smartness is identified with a general concept of innovation and with a substantial use of technologies-precisely those technologies that the economic actors involved in this process of enhancing the public good are able to provide. (82)
35	• Smart city is a global type of research and urban strategies aimed at improving the citizens' quality of life in metropolitan areas and at leveraging innovation and high technologies to solve the hard problems generated by the increasing

	urbanization. (862)
36	• The concept could be briefly described as cities that use information and communication technologies in order to increase the quality of life of their inhabitants while contributing to a sustainable development. (267) • A smart city is related to the learning capacity of their citizens and institutions, dealing with the relationships between local communities that advanced in the solution of their common problems. (277)
37	• "Smart city" as a generic term to describe IT-based innovative urban ecosystems. (218) • Smart cities form a dense innovation ecosystem with extensive social interactions from a knowledge workforce that creates economic value through the acquisition, processing, and use of information. (223)
38	• A city could be considered smart even if it has no ICT-based infrastructure or services but it serves local needs with intelligence (i.e., Geneva). However, the paradox is that all the smart city standards consider such intelligence to be based on the ICT, although they provide city performance indicators that measure all types of local capacity. (146) • People must reconsider their expectation from a smart city and realize that it aims to improve local living against some challenges (climate change, economic growth, etc.) and to enhance city planning. (146) • The evidence showed that smart city first a city, while smartness-gained by cyber-physical intelligence and service- is another asset, which either improves/automates typical functions (transportation, waste management etc.) or generates jobs and increases citizen satisfaction (from traffic awareness, energy efficiency etc.). (147)
39	• Smart cities can be also understood as places generating a particular form of spatial intelligence and innovation, based on sensors, embedded devices, large data sets, and real-time information and response. (120) • Smart cities therefore need to develop strategies and migration paths regarding how they will make use of available Internet infrastructures, testbed facilities, applications and know-how, and how they will develop public-private partnership for their access, use, and exploitation. (122)
41	• Technology is central to defining a smart city, but a smart city is not built simply through the use of technology. Technology is a means to enable social, environmental, economic, and cultural progress. (52) • The meaning of "smartness" should be considered as a relative term, not as an absolute term. (58) • A smarter government has a strength in making substantial improvements in the current situations while adjusting to the given, difficult-to-alter circumstances. (58)
43	• In cities, therefore, the interaction between citizens and the different institutional, urban and technological elements should be facilitated, making their daily lives easier, and providing them access to education and culture together with environmentally sustainable growth. This, together with the use and application of ICTs, helps provide citizens with an infrastructure that allows

	for an improvement in their quality of life and their active participation in the life of the city, sustainable growth and an efficient use of resources. (272) • Our idea of a smart city, therefore, is a broad concept and related to the efficient management of the intangible capital of a city: efficiency improvement in all area; proper cost management; transparency for the public; provision of information and communication infrastructures that enable cities to become centers for the production and dissemination of information in all area; new approaches to participation and urban governance; and provision of content to urban spaces, fostering scientific, cultural and, of course, entrepreneurial activities. (274)
44	• A general definition involves the implementation and deployment of information and communication technology (ICT) infrastructures to support social and urban growth through improving the economy, citizens' involvement and government efficiency. (556)
45	• I argue that, as a matter of urban policymaking, the smart city acted as an extension of existing, globally oriented entrepreneurial economic development strategies. (537)
46	• Considering diverse local institutional design, context, and different aspects of smart solutions experiences, one might say that it is not possible to identify a one fits-all definition of a smart city. (1033) • Therefore, the key elements of a smart city include utilization of networked infrastructure, business-led development as well as soft infrastructure that includes more humanist aspects such as knowledge networks, voluntary organizations, social capital, ordinary people and communities; also, social and environmental sustainability. (1035) • The smart city concept is a multidimensional urban development strategy by which people enable the city and are empowered through the utilization of technology. (1035)
47	• On the one hand, the notion of a 'smart city' refers to the increasing extent to which urban places are composed of 'everyware' that is, pervasive and ubiquitous computing and digitally instrumented devices built into the very fabric of urban environments […] that are used to monitor, manage and regulate city flows and processes, often in real-time, and mobile computing […] used by many urban citizens to engage with and navigate the city which themselves produce data about their users […] (2) • A smart city is one whose economy and governance is being driven by innovation, creativity and entrepreneurship, enacted by smart people.(2) • One significant aspect of the smart cities concept is the production of sophisticated data analytics for understanding, monitoring, regulating and planning the city. (12)
48	• 10 characteristics of smart cities: 1) technology, ICT, internet, 2) human and social capital development, 3) promotion of entrepreneurship, 4) global collaboration and networking, 5) privacy and security, 6) locally adapted strategies, 7) participatory approach, 8) top-down coordination, 9) explicit and workable strategic framework, 10) interdisciplinary planning

	• [S]mart cities today stand for a multidisciplinary subject of interest, constantly shaped by thinking about urban development, economic growth, and urban technology. (3) • As data management, knowledge codification, and information exchange are essential characteristics of smart cities, networking technologies have a fundamental role in all smart city strategies (15)
49	• A Smart City is an agglomerated area affected by a high concentration of learning and innovation as a result of creative citizens and institutions as well as the implementation of a digital infrastructure with the overall objective of achieving economic growth and a high quality of life, while keeping in mind the scarcity of natural resource. (214) • Six characteristics of a smart city: • 1) Availability and quality of ICT infrastructure and usage 2) Business-led urban development 3) Social inclusion of urban residents in public services 4) High-tech and creative industries 5) Role of social and relational capital 6) Social and environmental sustainability
51	• A smart city aims to resolve various urban problems (public service unavailability or shortages, traffic, over-development, pressure on land, environmental or sanitation shortcomings and other forms of inequality) through ICT-based technology connected up as an urban infrastructure. (82) • Smart cities are envisioned as creating a better, more sustainable city, in which people' quality of life is higher, their environment more livable and their economic prospects stronger (82)
52	• The smart city is mainly a new opportunity related to investments in ICT services and infrastructure. (1768) • In order to be smart, it sounds plausible that a city looks for a balanced development of both physical and intangible infrastructures under a proper institutional framework. (1782)
53	• First and foremost, progressive smart cities must seriously start with people and the human capital side of the equation, rather than blindly believing that IT itself can automatically transform and improve cities. (315) • Second, the progressive smart city needs to create a real shift in the balance of power between the use of information technology by business, government, communities and ordinary people who live in cities (Amin et al., 2000), as well as seek to balance economic growth with sustainability. (315)

B. Declaration of Contribution

This thesis is made with four published/unpublished articles co-authored with promoter and co-promoter. This section explicitly declares each author's contribution of the articles.

1. Identifying the results of smart city development: Findings from systematic literature review
    a. Yirang Lim: first and correspondent author, conceptualization, data curation, methodology, writing-original draft
    b. Jurian Edelenbos: second author, conceptualization, supervision, writing-review & editing
    c. Alberto Gianoli: third author, supervision, methodology, writing-review & editing
2. What is the impact of smart city development? Empirical evidence from a Smart City Impact Index
    a. Yirang Lim: first and correspondent author, conceptualization, data curation, methodology, writing-original draft
    b. Jurian Edelenbos: second author, conceptualization, supervision, methodology, writing-review & editing
    c. Alberto Gianoli: third author supervision, writing-review & editing
3. Smart Energy Transition: An Evaluation of Cities in South Korea
    a. Yirang Lim: first and correspondent author, conceptualization, data curation, methodology, writing-original draft
    b. Jurian Edelenbos: second author, conceptualization, supervision, writing-review & editing
    c. Alberto Gianoli: third author, supervision, methodology, writing-review & editing
4. Governance in Making Smart Cities: Insights from the Governance of Korean Smart Cities
    a. Yirang Lim: first and correspondent author, conceptualization, data curation, methodology, writing-original draft
    b. Jurian Edelenbos: second author, conceptualization, supervision, writing-review & editing
    c. Alberto Gianoli: third author, supervision, writing-review & editing

C. Propositions

1. In the current smart city literature, there is less attention to negative than positive impacts of smart city developments. (this PhD thesis)
2. Positive impacts are highlighted in high-income countries while the negative impacts are relatively more emphasized in middle- to low-income countries. (this PhD thesis)
3. Although environment and governance are major aspects of smart cities, there is less attention to them in practice and research. (this PhD thesis)
4. Smart city development requires collaboration among public, private, academic, and civil initiatives to yield positive impacts. (this PhD thesis)
5. South Korean smart cities showed better performance in economic, environmental, social, governance, and technological dimensions than non-smart cities. (this PhD thesis)
6. When sustainable development becomes a normative goal for almost everything (not limited to cities), it at the same time fades in meaning.
7. Participatory governance is desirable but people hardly participate because they are too busy with their lives.
8. The only way to achieve sustainable development is through life-long learning and education.
9. False information about COVID-19 on the internet does more harm to people than the pandemic itself.
10. People are concerned with privacy so much that they lose it when the governments want to use phone data to control the pandemic, but they have no problem using apps that knowingly and unknowingly collect personal data.
11. Hope smiles on effort[1].

[1] From 'The Professor' by Charlotte Brontë

D. Curriculum Vitae

Yirang Lim

Education

08.2017- Present PhD candidate
Erasmus University Rotterdam, Institute for Housing and Urban Development Studies (IHS), the Netherlands
- Thesis (working title): Impact of smart city development in urban sustainability

09.2014- 09.2015 Master of Science in Urban Management and Development
Erasmus University Rotterdam, Institute for Housing and Urban Development Studies (IHS), the Netherlands
- Major: Urban Environment Management & Climate Change
- Thesis: Enhancing city adaptive capacity through u-eco city development: the case of Songdo International City

03.2012- 02.2014 Master of City Planning
Seoul National University, Graduate School of Environmental Studies (GSES), South Korea
- Major: Environmental Planning
- Thesis: Concentration of large housing builders in Korean housing supply market

03.2006- 02.2011 Bachelor of Science, Yonsei University, South Korea
- Major: Housing and Interior Design
- Minor: Economics

Publication and Conference Participation

1. Lim, Y., Edelenbos, J., Gianoli, A. "Smart Energy Transition: an Evaluation of Cities in South Korea", *Informatics*, 6(4), 50; http://doi.org/10.3390/informatics6040050 (registering DOI), 2019.
2. Lim, Y., Edelenbos, J., Gianoli, A. "Smart Energy Transition: Evaluation of cities in South Korea", AESOP Annual Congress, July 9-13, Venis, Italy, 2019.
3. Lim, Y., Edelenbos, J., Gianoli, A. "Identifying the results of smart city development: findings from systematic literature review", *Cities: the international journal of urban policy and planning*, 95, doi:10.1016/j.cities.2019.102397, 2019
4. Park, J., Lim, Y., Kim, K., Wang, H., Revisit to incremental housing focusing on the role of a comprehensive community centre: the case of Jinja, Uganda", International Journal of Urban Sciences, 23(2), pp.226-

245, 2019.

5. Lim, Y., Gianoli, A. “Sustainable economic development through building adaptive capacity for sea level rise: a case study of Incheon, South Korea”, 52-53, *Program and Abstract Book,* Fifth World Sustainability Forum, 7-9 September 2015, Basel, Switzerland, 2015.
6. Choi, M.J., Lim, Y., and Park,G.J. “Empirical evidences of Korean urban development model for mass production of housing”, *Journal of Korea Planners Association*, 49(4), 141-153, 2014. [written in Korean]

Work Experiences

04.2016- 07.2017 Assistant Research Fellow, Korea Research Institute for Local Administration, Regional Development Research Center

- Master Plan Revision for Yeonpyeong, Daecheung, and Baekryeong islands (2017~2020)
  - Provided research work in the development of literature review and current condition analysis
  - Organizing field trips, meetings, and reports
- The 4th Master Plan for Islands in South Korea (2017~2027)
  - Provided research work in policy review and data analysis on demographics, economy, and society of Islands in South Korea

07.2013- 06.2014 Assistant Research Fellow, Korea Research Institute for Human Settlements (KRIHS), Housing & Land Research Division

- Knowledge Sharing Program with World Bank, ‘Development of an incremental and affordable housing development policy toolkit and pilot city case studies (Uganda/Philippines)’
  - Provided research work in the development of the literature review for Uganda case study
  - Organizing field trips, workshops, and dissemination seminars
  - Liaison to World Bank staff and local consultants
- A research project, ‘A study on housing affordability measures and standards for policy applications’
  - Provided research work on international cases of housing affordability measure
  - Editing and managing publication

05-11. 2011 ODA Young Professional, Korea International Cooperation Agency (KOICA), Uganda Office

- Managing NGOs, which Uganda Office financially supported
  - Assisting interim evaluation
  - Organizing KOICA-NGO workshop
- Conferences participation
  - International conference for Local Development Partner Group in Uganda
  - National Rice Stakeholders' Workshop
- Designing and publishing KOICA Uganda Office brochure

02-04. 2011 Intern, Korea Employment Information Service, Employment Forecasting Center

- Editing bimonthly magazine 'Employment Issue'
- Collecting and analyzing data for publishing 'Korea Job Dictionary'
- Preparing kick-off workshops for 12 research projects