UNDERSTANDING AND EVALUATING SUSTAINABLE URBAN TRENDS: CASE STUDIES FROM CHINA AND JAPAN

By

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ABSTRACT

The advent of the Brundtland's Report *Our Common Future* in 1987 and the successful launching of the Rio Earth Summit in 1992 has built international consensus on "sustainability" as a new paradigm for development. The development of "eco-cities" has become an international phenomenon for the creation of more sustainable urban areas. Subsequently, the negotiation of the Kyoto Protocol in 1997 supported another global wave of "low-carbon cities" development. Additionally, since the early 2000s, the development of information and communication technologies has become the impetus for an innovation-oriented sustainable urban trend known as the "smart cities". However, despite the enthusiastic advancement of these new urban models worldwide, there is still a lack of consensus regarding systematic approaches or methods for the standardization and evaluation of these trends.

This thesis aims to investigate and examine three global trends of sustainable cities with case studies from China and Japan, in both quantitative and qualitative perspectives, to understand their defining features and components. Furthermore, this thesis intends to propose and develop a methodical approach for the evaluation of these urban development models to have flexibility in relation to local inputs, and applicability to other similar urban initiatives or projects.

For the "eco-cities", this thesis reviews studies regarding concepts, frameworks and indicator systems, A large amount of literature on the selection of indicators under a singular framework in China is observed rather than having a quantity comparison from a broader scope. To obtain a quantitative sense of how effective China's eco-cities are compared to other best practice in the international arena, two cases from China and Japan have been selected to examine their indicator values under the national eco-city framework of China. Gaps between economy related indicator values are identified, suggesting lower average economic values and energy efficiencies of Chinese eco-cities. Targets concerning the waste sector are also lower for China than in Japan. The environmental indicator values show lower levels than in the other two cases as well, while social indicators entail a specific methodological approach for measurements in China. Suggestions are made in the discussion section based on the outcomes of the aforementioned comparisons, to provide a reference for the future development of other eco-cities.

The ensuing study on low-carbon cities employs a qualitative view of these policies such as "garden city" to "low-carbon city" to determine the how the environment-related urban environmental policy developed during different periods in China. Case studies of leading low-carbon cities are examined and analyzed to obtain insights regarding their urban environmental policies as well as the implications of their successes and limitations. The major findings indicate that government policy and financial support played a significant role in transforming the industrialized city of Kitakyushu into a center of low-carbon sustainable practices in Japan's case. Local autonomy and flexibility in policymaking and civic participation profoundly contributed to the successful switch to renewable energy. These experiences could serve as useful references for China's low-carbon city development from different perspectives.

Next, the literature regarding smart city phenomena is thoroughly reviewed. Despite a lack of universal consensus, there seems to have been two major streams of SC concepts with overarching strategies for comprehensive SC development, with specific focuses on utilizing information and communication technologies to improve the quality of life. Key features and components of smart cities are then summarized, consolidated into a proposed framework consisting of two main objectives, six domains, and two means for implementation. Furthermore, a customized smart city index for the City of Kitakyushu in Japan is proposed as a case example for the application of the proposed framework. The outcomes of this section provide new approaches for understanding smart city concepts and evaluating the on-going smart cities in Japan and potentially in other countries.

As a continuation of the previous section, a further refined selection of indicators from the proposed smart city index based on stakeholder inputs from Kitakyushu City is conducted. These indicators are then weighted by expert opinion surveys using the analytical hierarchy process (AHP) method. This weighted smart city index can be useful for prioritization of policy implementation or selection of key performance indicators (KPIs). More importantly, this integrated approach consisting of three main steps from conceptual understanding to index development and indicator weighting is found to be customizable and potentially applicable to other urban development models in different local settings. This finding would contribute to a more insightful understanding of sustainable urban projects and their evaluations for policy makers, urban planners and city managers.

The findings and outcomes of this dissertation contribute to the existing literature on urban sustainability with elaborated studies on “Eco-city”, “Low-carbon City” and “Smart City” in terms of comprehension and evaluation. The conceptualized integrated method for urban development evaluation can offer practical references for policy makers, and urban managers, as well as to academia for further research.

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DEDICATION

To my most beloved father, who passed away on July 11, 2016

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ACRONYMS

ACEF	ACEF
AHP	AHP
AHP	Aggregated Weights
BOD	Biochemical Oxygen Demand
CAS	Chinese Academy of Sciences
CO	Carbon Monoxide
COD	Chemical Oxygen Demand
CR	Consistency Ratio
EIU	Economist Intelligence Union
EU	European Unions
EV	Electric Vehicles
GCR	Group Consensus Ratio
GDP	Gross Domestic Product
GHG	Green House Gases
ICE	International Electronic Commission
ICT	Information and Communication Technologies
IGES	Institute for Global Environmental Strategies
ISO	International Organization for Standardization
KPI	Key Performance Indicators
MAB	Man and Biosphere
MAUT	Multi-attribute utility theory
MEP	Ministry of Environment Protection
METI	Ministry of Economy, Trade and Industry

MoC	Ministry of Construction
MHURD	Ministry of Housing, Urban-Rural Development
NAIADE	Novel Approach to Imprecise Assessment & Decision
NDRC	National Development and Reform Committee
NGO	Non-Governmental Organization
NO2	Nitrogen Dioxide
NPO	Non-for Profit Organization
OECD	Organization for Economic Co-operation and
P	Prosperous
PM10	Particulate Matter of 10 Microns in diameter or smaller
PM2.5	Particulate Matter of 2.5 Microns in diameter or smaller
PPM	Parts Per Million
QoL	Quality Of Life
RGMM	Raw Geometric Mean Method
SC	Smart City
SEG	System Evaluation Group
SO2	Sulfur Dioxide
UN	United Nations
UNEP	United Nations Environmental Programme
UNESCO	United Nations Educational, Scientific and Cultural

1 INTRODUCTION

1.1 Background of Research

Twenty-five centuries ago, the great philosopher Aristotle defined cities as "Built Politics". In the 21st century, cities are the most complex and dynamic eco-systems globally and the centers of scientific, cultural and social innovations (Glaeser, 2011; Hall, 1998), yet still face human-lead, dynamic and shifting challenges (Mega & Pedersen, 1998). The recorded history of human civilization can also be identified as the process of globalization and urbanization (Calderoni et al., 2012).

According to the United Nations (UN), the global population reached 7.2 billion in 2013 and is expected to reach 8.1 billion by 2025, and 9.6 billion by 2050. More than half of them (53% in 2015) are living in urban areas, and the urbanization rate is expected to reach 59.9% by 2030, and 67.2% by 2050 (United Nations, 2015). Continent-wise, the highest urbanization rates are seen in North America (81%), Latin America and the Caribbean (80%), Europe (73%), and Oceania (70%) while Asia and Africa's urbanization rates are still below the world average with 47% and 40% perceptively (United Nations, 2015).

The promising prosperity of civilization that advanced alongside fast urbanization also brought devastating "side effects" for human societies such as resource scarcity, energy crisis, eco-and-environmental hazards, climate changes related disasters, slums, poverty, pandemic and the list goes on. Particularly the developing countries in Asia and Africa are experiencing the world's worst urban environmental pollutions, and this poses enormous threat to human health. The United Nations Environmental Programme (UNEP) estimated that urban air pollution causes one million premature deaths each year and costs 2% of the GDP in developed countries and 5% in developing countries (Fook & Gang, 2010, p. 2).

Long before the creation of modern days' environmental urban policy, great visionaries like Ebenezer Howard (1850-1982) had already appealed for a new way of harmonious human nature relationship – the "Garden City" (Imura, 2010). As global consensus gradually aligned on the realization that "business as usual" development mode could no longer guarantee the effective long-term prosperity for human societies, the pursuit of a different paradigm for development has been explored continuously, particularly in the urban development context.

The subsequent mergence of “New Towns” of the UK spread around the world and shaped the modernist urban planning doctrine during the rapid urbanization after the Second World War (WWII). The Ecological Modernization (EM) was developed as a macro-theoretical model addressing the importance of sustainable development that emerged at a later stage. Other concepts like “Regenerative Development” and “Positive Development” also presented different approaches in addressing more effective ways to plan and develop cities from complex social, ecological and physical challenges in the urban sphere(Boğaçhan, 2016).

Two significant publications in the 1970s and 1980s initiated and accelerated the global consciousness on “sustainable development” or “sustainability”, namely, the Club of Rome’s *Limits to Growth* (Meadows et al., 1972) and the Brundtland Commission’s Report *Our Common Future* (World Commission on Environment and Development, 1987). The first one, though comparatively less acknowledged than the later one, presented from an historical point of view the arguments made by Thomas Malthus in a modern context regarding population overgrowth, and the excessive burdens imposed on ecological limits of agricultural products leading to the consequently depopulation. And over one decade later, the Brundtland Report brought forth the concept of “sustainable development” which, though vague in definitive terms, heated up the conversations and dialogues in the world’s forums for leaders of the globe (Holden et al., 2008).

Later in 1992, when the United Nations Conference on Environment and Development (also known as the “Earth Summit”) took place in Rio de Janeiro, “sustainable development (or sustainability)” became the core principle for urban and environmental developments. After the ratification of the Kyoto Protocol (and a range of subsequent international conventions) by the majority of countries in 1997, “low-carbon” became a “new norm” for sustainable development. These international conventions and protocols have given rise to some new global trends for urban development such as “Green City”, “Eco-City”, and

"Low-carbon City", with the most recent urban trend under the information era – known as the "Smart City".

Post-colonial urban theory emphasizes that cities vary in shapes, sizes and forms with distinctive cultural and historical backgrounds. Therefore urban development needs to be framed into local context and contents. Though seeking universality in single sustainable urban framework or indicator set may appear dimly possible, having a certain flexible and customizable method or approach that is subject to locality would presumably benefit project developers and stakeholders.

Numerous sustainable city (or urban) projects, initiatives and programmes have been developed or being pursued on globally. They vary in geographical features, socio-demographic contexts, and implementation scales. On the one hand, various organizations, institutes and scholars have spent great efforts in developing relevant concepts, frameworks or indicator systems (or index) under the broad sustainability framework: on the other hand, there is not yet any single or universally accepted framework that applies to all the different conditions of various regions.

This thesis aims to examine the three most recent urban development trends, namely, "eco-cities", "low-carbon cities" and "smart cities" under an East Asia setting. China and Japan are selected as the two major case study areas (with other international references) to provide better understandings of these urban trends regarding concepts, frameworks and evaluation method such as indicator systems or indexes. And finally, a method or approach with high customizability from local context is proposed based on the previous steps taken. This thesis would fill in the existing research gap of lacking such method in understanding and evaluating urban trends, and shed some light on meaningful and practical methodologies for urban studies.

1.2 Thesis Objectives and Research Questions

The sustainable urban development trend or sustainable cities continuum manifest an array of different concepts, models and categories. Concepts like "Garden Cities", "Green

Cities", "Eco-Cities", "Low-carbon Cities", "Intelligent Cities", "Smart Cities" and many more can all be regarded as part of the overarching "Sustainable City" metanarrative.

The objectives of this thesis, besides answering the research questions, are to distill or propose a customizable and pragmatic method or approach for understanding the urban development trends and their evaluations. The outcomes of this thesis would provide some insightful references in translating the urban policy goals and objectives into reality with different local conditions.

This thesis revolves around two overarching research questions distilled from this era of urban sustainability seeking and discerning, namely,

1) **How to understand sustainable urban development trends such as "eco-city", "low-carbon city" and "smart city" in specific local contexts;**

2) **How to analyze and evaluate these sustainable urban trends using a proper methodical approach with local and regional inputs.**

To answer these two major research queries, a set of subsidiary questions was developed under the urban sustainable trends selected for this thesis. These urban trends can be developed into two parts according to their chronological occurrence and relevance. The first tackles the topics of "eco-city" and "low-carbon city"; the second part discusses and analyzes "smart city" and the "evaluation scheme or method". The following arrangement of questions have been embedded in each chapter to navigate the research flows of this thesis. The specific research questions are detailed in their corresponding chapters:

Regarding "Eco-cities"

- What are "eco-cities" in terms of origin, concept, frameworks and indicator systems? And what is the current status of eco-city development in China and Japan?
- Given the many studies regarding eco-cities, how exactly are China's eco-cities performing compared to other best practices on a global stage?

Regarding "Low-carbon Cities"

- What constitute "low-carbon cities" and their development status globally? And what is the current status quo of developing low-carbon cities in China with international references.
- What could be the implications or references from international examples for China's?

Regarding "Smart Cities"

- What is the current status quo of "smart cities" given their infancy stages as the newest global trend for urban development?
- Given the diversity in its interpretation, are there any common features that smart cities should incorporate or mutual framework for its comprehensions?

Regarding "Evaluation Scheme or Methods"

- What are the current evaluation systems for smart cities, and how are they evaluated?
- What could be effective methods or mechanism for smart city index or indicator systems for evaluating smart cities or other sustainable cities?

1.3 Adopted Methodologies

There are several methods adopted and applied for the four major research packages included in Chapter 3 to Chapter 6. The specific steps and descriptions are detailed in each chapter; here I generally summarize the major methodological approaches:

In Chapter 3, I first conduct systematic reviews of eco-cities regarding definitions, frameworks, indicators and related works both abroad and in China. I take a quantitative approach for comparing and analyzing China's eco-city standards with a best-practiced case study from Japan, to obtain a quantified sense of their performances for later policy analysis and recommendations. The data used for these comparisons are from governmental records and documents, official statistics, in some cases, interviews are conducted for specific information or data that are not available through published records.

Chapter 4 starts with an in-depth review of the low-carbon city and its relative development status quo focused in China and Japan. Another Case of a German City is included as comparison. Different from the previous chapter, a qualitative approach is adopted for answering my research questions. Field trips are conducted for data collection, in-person interviews for case study analysis, based on which, a series of policy recommendations is proposed regarding the low-carbon city developments in China. Secondary data were also used in the absence of primary data for analysis.

The next two chapters (5 & 6) take an integrated approach combining both qualitative and quantitative methods. After thoroughly reviewing the literature on smart city concepts and framework, and a policy analytical pool is then applied to analyze them. Based on these results, an encompassing conceptual framework is proposed and applied with a case study in Japan. I then propose an index with carefully designed indicator identification and selection and steps, and establish a compete index for smart city evolutions. Then I conducted an experts survey for quantitatively weighting of the indicators. And finally, the approaches and steps taken were summarized into an integrated method for the evaluations of sustainable urban development models.

Literature and data are from peer-reviewed publications, and published governmental or organizational records with high credibility. Primary data for the indicator selections are collected in workshops of local stakeholders in Kitakyushu City. Indicator weighting were calculated by the excerpt survey results.

1.4 Structure of the Dissertation

The remaining parts of this dissertation are arranged and summarized as follows:

Chapter 2 reviews the major works, theories and thoughts regarding urban studies in general, and concepts and development of the studies or researches on eco-cities, low-carbon cities, and smart-cities. This chapter offers general information regarding both theories and current practices of the topics enlisted in the thesis.

Chapter 3 investigates the urban policy frameworks and the current practices in China’s major cities, with comparative introductions between the past standards of Chinese eco-cities and that of the current ones, on both national and provincial levels. Furthermore, this chapter compares the eco-city standards with the Suzhou Case in China and an international acknowledged Japanese eco−city of Kitakyushu by analyzing the key indicators from selected eco-city case studies.

Chapter 4 reviews these policies with particular focus on the “low-carbon” cities in China. Additionally, two case studies of Kitakyushu city in Japan and Rhein-Hunsrück District in Germany are examined and analyzed to obtain enlightening factors in terms of their urban policies as well as the references and implications from their successes and limitations. These experiences could offer insightful references to China’s low-carbon urban developments from different perspectives.

Chapter 5 summarizes the key features and components of smart city and proposes a conclusive framework for smart cities that consists of double-objectives, six domains and two means for its realization. Furthermore, this chapter proposes a customized indicator system based on the SC framework for measuring the “smartness” of the smart cities in Japan, and includes a case study of the city of Kitakyushu. The outcome of this chapter provides some new insights to the methodological approaches adopted to assess the on-going smart city initiatives in Japan.

Chapter 6 further improves the proposed smart city conceptual framework of Chapter 5. Under this framework, I have further refined the selection of smart city indices based on the inputs from the stakeholders in the City of Kitakyushu. Revisions and modifications have been made to the proposed SC Index. The Analytical hierarchy process (AHP) is applied for the weighting of indicators by experts’ survey. Finally an integrated approach is recognized as the outcome. This integrated approach is found to be highly customizable and adoptable for potential applications to other urban development models in different contexts for both framework development and index composition.

Chapter 7 summarizes the major findings of the thesis and denotes the contributions and significance of the research outcomes as well as the limitations for each conducted topic. Further discussions are conducted and the possible perspectives and directions are pointed out for future research.

2 REVIEW OF LITERATURE

This chapter[1] reviews some prominent urban theories are claimed to be the fundamental frameworks of the urban studies discipline. Major definitions and concepts, frameworks and historical developments, as well as major and influential studies are reviewed regarding a range of topics from Garden City to Eco-Village and Eco-City, from Low-carbon City to Smart City. Due to the arrangement of the thesis, additional and more specific reviews of literature are conducted in subsequent chapters.

2.1 Urban Development Trends Towards Sustainability

2.1.1 Historical Background

In history, urban development and city formations were driven by several factors, such as religion, politics and industrialization In the early 1800s, the industrialization-led economic growth brought mobility and technology to urban settlement and development, which boosted the transformation from agricultural society into urban society as population growth accelerated (Bayulken & Huisingh, 2015). The past two centuries has seen an increase in the number of cities and their sizes, which dramatically has changed the urban landscape (Bayulken & Huisingh, 2015).

In the early 1790s, the Malthusian theory of "environmental limits" concerned the relationship between population growth and the food resources, claiming that human population would decrease due to the increasing food scarcity (Girardet, 2003). However, what is seen today is a deteriorating ecosystem (Mebratu, 1998) and continuously growing population (Mickwitz et al., 2011). Moreover, the human-based greenhouse gas

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[1] Some of the contents regarding eco-villages and low-carbon cities from this chapter have been published as two book review articles in the journal *Asia Pacific World (Zou, 2015a, 2015b).*

(GHG) emissions in cities are estimated to make up to 70% of the total GHG emissions (United Nations, 2015). The need for new urban development paradigms and having new urban models is therefore paramount.

Early discussions regarding sustainability or sustainable development (these two terms are used interchangeably heretofore) were seen in the 1960s, and appealed for the need to change the system broadly and holistically (UN-Habitat, 2011). In some regions, the grassroots level movements paved the way towards a rippling awakening of environmental consciousness even since the early 1950s. Rachel Carson's *Silent Spring* in 1962, for instance, was one of the representative pieces at that time.

The United Nations Conference on Human and Environment (UNCHE) that took place in Stockholm in 1972 is regarded to have laid the groundwork for international consensus building on environment versus development (Birkeland, 2012). One prominent subsequent publication of the *Brundtland Report* (Quental et al., 2009) depicted the major challenges faced by mankind and called for changes towards sustainable development (SD) or sustainability. Despite the limitations of SD concept (World Commission on Environment and Development, 1987), it became one of the most influential discourses for all-encompassing institutional changes at both national and local levels (Birkeland, 2012), and tried to address full spectrum of social, economic, environmental issues from a long term prescription for growth (Khakee, 2002).

Since the 1980s, another concept of ecological modernization (EM) emerged as a complementary discourse to SD as noted by Langhelle (2000). He argued that well SD might be more broad and comprehensive in concept, and that EM revolved around SD but with clear focus towards certain pressing aspects such as economic and ecological dimensions in societal development (Langhelle, 2000). Under such a background, a range of different city models were seen consisting of major sustainable urban development trends in the following decades, with each of them somehow overlapping with each other, while addressing various goals or objectives, dimensions or themes, methods for implementation in different corners of the world.

2.1.2 Sustainable Urban Categories and Trends

A plethora of proposed sustainable city models, titles or urban development categories has emerged in the past couple of decades. These initiatives and programs vary in sizes, scales and locations under a multitude of diverse geo-political, and socio-cultural settings. Policy makers, city planners and developers often use these categories interchangeably without drawing clear distinctions of their conceptual perspectives (Bayulken & Huisingh, 2015). Terminology wise, some call them urban or city models, initiatives, programs or categories without offering a standard typology. Herewith, they are referred as sustainable urban models or categories, a cluster of which makes a sustainable urban "trend".

Some of these urban categories have been thoroughly reviewed by (Jong et al., 2015) including: "sustainable cities", "green cities", "livable cities", "digital cities", "intelligent cities", "smart cities", "livable cities", "digital cities", "intelligent cities", "smart cities", "knowledge cities", "information cities", "resilient cities", "eco cities", "low carbon cities", and even combinations such as "low carbon eco cities" and "ubiquitous eco cities" etc. Even though each of these terms appear to address certain core aspects of urban transformation towards sustainability, there are many overlapping parts in their concepts, or blurry definitions are seen under a closer examination.

They systematically analyzed a total of 1430 academic articles from Scopus and Web of Science databases between 1996 to 2013, regarding the emerging city categories and their occurrence frequencies （refer to Table 2-1）. They found that twelve city categories have different levels of significance in literature, indicating that "sustainable city" is the most common category, followed by "Eco city", "Smart City" and "Low carbon city" etc. (Jong et al., 2015). It can be observed that some conceptually distinctive identities of the city categories emerged with overlaps or cross-fertilizations emerged in different periods of time.

From a regional-specific point of view in East Asia, both China and Japan have brought up national policies regarding "sustainable city" development on a macro-level. Through slightly different in terms, three major trends can be observed, namely Eco (Garden) City, Low-carbon City, Smart City in China; Eco-town, Low-carbon Society, Smart City in Japan, which have been promoted under different governmental entities (refer to Table 2-2).

Table 2-1 Number of Urban Categories Appeared in Scopus Database Search

Category	**Number of articles**
Sustainable city	546
Smart city	222
Digital city	166
Eco city	133
Green	105
Low carbon city	93
Knowledge city	82
Resilient city	47
Intelligent city	33
Ubiquitous city	29
Livable city	26
Information city	23

Source: (Jong et al., 2015)

Table 2-2 National Policies of Sustainable City Development in China & Japan

"Sustainable City" Policy in China		**"Sustainable City" Policy in Japan**	
Development Policy	Governmental Entity	Development Policy	Governmental Entity
Eco-City	MHURD	Eco-Town	METI & MoE
Low-carbon City	NDRC	Low-carbon Society	MoE
Smart City	MHURD	Smart City	METI

Source: Compiled by the author based on official government websites.

Note: MHURD stands for Ministry of Housing and Urban-Rural Development in China
NDRC stands for National Development and Reform Commission in China
METI stands for Ministry of Economy, Trades and Industry in Japan
MoE Stands for Ministry of Environment in Japan

By the reviewed concepts regarding city models and urban categories, as well as the regional policy regarding sustainable urban development, it can be concluded that "sustainable city" embodies a broad spectrum of city models or urban categories, with each addressing different or often overlapping aspects of urban development towards sustainability. Along the line of development, three major sustainable urban trends can be observed, namely, "eco cities", "low carbon cities" and "smart cities", in the East Japan context, particularly in China and Japan.

2.1.3 From Garden City to Eco-village

Early in the 1890s, Sir Ebenezer Howard (1898) initiated the "garden city" trend in his book *To-morrow: a Peaceful Path to Real Reform*[2] with the aim of promoting the concept of garden cities comprising planned and self-contained communities surrounded by greenbelts as well as carefully balanced area of residences, industries and agriculture (Fook & Gang, 2010, p.2). England during that period was in the throes of economic development, people were concentrating in cities, urban air pollution was worsening, and water quality was deteriorating in the Thames and other rivers while poor workers lived in deplorable housing districts that were steadily expanding (Imura, 2010, p.21).

Howard's Garden-City concept was to build, apart from large cities like London, small settlements where employment and housing were clustered closely together forming smaller cities with their residential areas surrounded by parks and other pursuits. His emphasis on the importance of a permanent girdle of open and agricultural land around the town soon became part of British planning doctrine that eventually developed almost into dogma[3]. His notion of the Garden City laid the foundations for modern urban planning and environmental policies and gave origin to later concepts for sustainable urban models like green cities and eco-cities.

In regard to another dynamism in rural sustainable development, eco-villages or eco-communities are the counterpart of its urban twin – Eco-cities. Litfin (2014) offers an inspiring perspective on up-scaling the principles from the global ecovillages that she visited to "glean for lessons" that can be applied in our daily lives, and, more importantly, translate

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[2] This book was re-printed in 1902 as *Garden Cities of To-morrow*
[3] http://urbanplanning.library.cornell.edu/DOCS/howard.htm

this thinking into action. Upon the completion of her visits to those ecovillages and the engagements with their villagers, she concludes that the four pillars for achieving sustainability are: ecology, economics, community and consciousness. All of these pillars are depicted and illustrated with observations as well as dialogues and interviews with members of the ecovillages from which enlightenment, reflections, and occasional critiques are distilled and discussed, each in their own separate chapter.

She did try to address the various aspects of Eco village life including, permaculture, building, energy, water, food, transportation, collaborative consumption and wildlife conservation. While many of the Eco village case studies are from Europe and the American continents, four examples can be found in Asia. Examples such as the Auroville in India, the Sarvodaya Eco-village in Sri Lanka and Konohana County in Japan indicate that this “new norm” of universal mega-narrative has roots that are not unique to the industrialized sphere but also can be found in the Asia-Pacific regions, where a new era of global geopolitics and socioeconomics is dawning.

The efforts to curb the negative impact of urbanization are neither new for people nor confined to particular countries. Concepts like “Garden City”, “New Town” and “Techno-City” that occurred in the 19th and 20th Century are some of the major representatives (Joss et al., 2011). Later concepts or terms like “Climate-Neutral City”, “Low-Carbon City”, “Smart City”, and “Sustainable City” can also be considered as sister terms of the broad urban sustainability concept, which “covers various notions of, and approaches to, sustainable urbanism, rather than a conceptually coherent and practically uniform phenomenon” (Joss, 2012).

2.1.4 Eco-cities

Developing “eco-cities” has been considered as a major approach for achieving sustainability in urban areas. The early idea of “eco-cities” was brought up in United Nations

Educational, Scientific and Cultural Organization (UNESCO)'s Man and Biosphere (MAB[4]) program in the early 1970s to propose, " an interdisciplinary research agenda and capacity building that target the ecological, social and economic dimensions of biodiversity loss and reduction of this loss". Based on this initiative, many scholars and experts from different domains have since then come up with their own definitions and interpretations of what "eco-cities" should look like, among them are scholars like Yanitsky (1981b) and Register (1987). The European Commission (1996) defines "eco-cities" as "to create the smallest possible ecological footprint of cities, producing the lowest quantity of pollutions possible improving efficiencies from energy, material, and economic terms". Different theories for developing "eco-cities" under specific titles also emerged along the "eco-cities" development timeline, such as, "green cities", "garden cities", "livable cities", "low-carbon cities", all addressing different aspects for their specific requirements of sustainable urban development.

The term "urban sustainability" was first coined by a group of visionary architects from the US called "Urban Ecology" with the mission to "use urban planning, ecology, and public participation to help design and build healthier cities" (urbanecology.org, 2013[5]). From the current point of view, their definition of "urban sustainability" is rather limited or narrowly focused on designing and planning terms.

A more concrete concept of "eco-city" was brought up by the "urban ecology" group with the idea of "reconstructing cities to be in balance with nature". And in 1990, they held the first international Eco-city Conference in California that drew over 800 people from 13 countries and initiated rigorous debates on eco-systems, transportation, environmental justice, and urban design with modern cities. This conference served as a wake up call, and there has been ever since various conferences on eco-cities across the globe. However it is only in recent years that the eco-city phenomenon has become truly global and mainstream,

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[4] http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/man-and-biosphere-programme/

[5] http://www.urbanecology.org/history.htm

against the background of a majority of people now living in cities and the growing international recognition of the scale of severity of climate change (Joss & Tomozeiu, 2013).

Currently, there are still no universally standardized criteria for what an "eco-city" should look like, nevertheless, a number of selection criteria have been commonly acknowledged and accepted as encompassing the perspectives such as economy, society, environment and ecology. To quality as an "eco-city", a settlement should contain several of the following criteria (Joss, 2011; Roseland, 1997):

- Operates on a self-contained economy, resources needed are found locally
- Has completely carbon-neutral and renewable energy production.
- Has a well-planned city layout and public transportation system that makes the priority methods of transportation as follows possible: walking first, then cycling, and then public transportation.
- Resource conservation – maximizing efficiency of water and energy resources, constructing a waste management system that can recycle waste and reuse it, creating a zero-waste system.
- Restores environmentally damaged urban areas
- Ensures decent and affordable housing for all socio-economic and ethnic groups and improve jobs opportunities for disadvantaged groups, such as women, minorities, and the disabled.
- Supports local agriculture and production
- Promotes voluntary simplicity in lifestyle choices, decreasing material consumption, and increasing awareness of environmental and sustainability issues.

Besides the above mentioned criteria, in terms of city design, Graedel (1999) points out that following principles should be embraced when defining an eco-city:

- The city must be sustainable over the long term
- The city must utilize a systems approach to evaluating its environmental interactions.
- The city design must be flexible enough to evolve gracefully as the city grows and changes.
- The open space of an eco-city must serve multiple functions.
- The city must be part of regional and global economies.
- The city must be attractive and workable.

During the 1980s to early 1990s, the concept of "eco-city" remained rather ideal with very few practical examples until the United Nations Earth Summit took place in Rio de Janeiro, 1992 and the resulting sustainable programme (Agenda 21). This formed the background to a first wave of practical eco-city initiatives such as Curitiba (Brazil), Waitakere (New Zealand), and Schwabach (Germany) that were promoted among other first-generation of eco-cites worldwide (Joss & Tomozeiu, 2013; Joss et al., 2011) .

Many Chinese scholars have also their interpretations regarding eco-cities. Yu (2009) proposes that an eco-city is "a process of delivering integrated social, economic and environmental development. The achievement of the eco-city would involve transforming production patterns and changing lifestyles…" Song (2011) takes a more comprehensive approach to interpret eco-cities as "cities that should include elements of harmonious development with human beings as a priority; coordination among social, economic and ecological benefits; concerns with the two 'E's (environment and economy); innovation; and the overall planning concept" (Yu, 2014, p.103).

"Influenced by the theory of the social-economic-natural complex ecosystem proposed by Ma and Wang (1984), Chinese scholars have generally considered eco-cities as a stable, harmonious, and sustainable complex eco-system that makes possible "all-win" development among social, economic, and environmental factors; full fusion of technology and nature; maximal motivation of human creativity; increasingly improved urban civilization; and a clean and comfortable environment" (Su et al., 2013, p.5).

Wang (2001) articulates, “Eco-city construction includes a high-quality environmental protection system, efficient operation system, high-level management system, good greenbelt system, and high social civilization and eco-environmental consciousness”. Su et al. (2013, pp.5-6) summarize the characteristics of eco-cities into the following seven points:

- 1. Health and harmony: In an eco-city the human support system is healthy and sustainable so that it can provide enough and consistent eco-system services. Further, all economic, social and natural ecological order in the temporal and spatial dimensions.
- 2. High efficiency and vigor: The “high consumption,” “high emission,” “high pollution,” and “low productivity” development modes are altered into more environmentally friendly modes in an eco-city. For instance, energy and materials are used with high efficiency, all industries and departments cooperate within a harmonious relationship, and the productivity of the system is correspondingly high.
- 3. Low-carbon orientation: Faced with the ever-present threat of climate change, low-carbon development should also be emphasized. This can be exemplified by higher resource productivity (i.e., producing more with fewer natural resources and less pollution), as well as by developing leading-edge technologies, by creating new businesses and jobs, and by contributing to higher living standards (Department of Trade and Industry, 2003) .
- 4. Sustaining prosperity: Regarding sustainable development as a basic guideline, resources will be reasonable located both spatially and temporally. In other words, the development of the current generation cannot jeopardize the development of the next generation. Thus, prosperity will be sustained in an eco-city.
- 5. High ecological civilization: In an eco-city, the concept of ecological civilization is displayed in and permeates all fields,

including industrial production, human day-to-day activities, education, community construction, and social fashion.

- 6. Holism: Eco-cities do not emphasize the improvement of single factors (e.g., economic growth or a good environment) but pursue optimal holistic benefits by integrating social, economic and environment factors. Aside from economic development and environment protection, holism emphasizes the comprehensive improvement of human living standards.
- 7. Rationality: Urban development depends on regional foundations in terms of natural conditions, the supply of resources, and the environmental capacity. Thus, the optimal development mode of each city is different from all others due to these different regional characteristics.

After reviewing the major books regarding eco-city development in the global west, Fook and Gang (2010) propose an eco-city model with three essential elements in environmental, economic, social and cultural terms in the Asian perspective, in hopes of enriching the exiting literature.

2.1.5 Low-carbon Cities

With the dawning of the 21st century, a new global trend for sustainable urban development formed the shape – “Low-carbon City”. Imura (2010, p.22-24) regards the low-carbon cities as an evolved or integrated concept of “eco-cities” themed in redesigning and equipping cities towards making “low-carbon society” a reality. He bases this notion on the philosophy that cities should contribute to the protection of the global environment by improving themselves.

In light of China’s vital transformation towards sustainable development modes, ample leading institutions of academia and industrial sectors to seek wisdom and synergies for China’s low-carbon city endeavors (Zou, 2015a). Wang et al. (2014c) review the global climate changes and major international organizations and protocols established as responses to the risks and challenges faced in society. They denote that urbanization coupled with a rapidly growing population is the major contributor to the increasing carbon emissions, and states the importance of establishing low-carbon cities. They also examine the current status of China's low-carbon initiatives, from national policies and frameworks to provincial level regulations and well-practiced cases. They also unveiled the problems and challenges faced during the pursuit of low-carbon city developments, based on which, a series of suggestions are proposed as references for solutions (Wang et al., 2014a).

Cha et al. (2014) address the issues from an international perspective. Examples from leading countries with renowned low-carbon projects, like the UK, Germany, and Sweden in Europe, the US and Canada in North America, as well as Japan and Australia in Asia, are examined with regard to their national and cross-national policies, best practices and references that can be applicable to China. However, little is mentioned concerning the "lesser" industrialized parts of the world, for example, South East Asia and Africa, where the future foci of urbanization and rapid industrialization are taking places.

Shen et al. (2014) offer a quantitative analysis contrasting the Chinese low-carbon initiatives and their international counterparts. They offer the readers a numeric sense of how well China's low-carbonization compares to the "norms" of overseas countries. Northam's theory (1979) of urbanization levels is applied as an analytical base, where highly urbanized countries (more than 70%) like the UK, Sweden, US, Japan and Brazil is compared to China using selected indicators. Countries with moderate urbanization (from 30% to 70%) like South Africa and Indonesia, and low urbanization countries (less than 30%) are also listed for a comprehensive result. Additionally, they also compare major metropolises and community level low-carbon developments using case studies, offering a holistic view of macro to micro, quantity to quality to the readers.

Zhang et al. (2014) introduce the urban planning concepts of Chinese low-carbon cities with successful case studies mostly coming from developed metropolitan areas like Shanghai and Beijing. Deng and Ye (2014b) review China's low-carbon industry sector, with particular references from Japan and the US to demonstrate the current technological trends in the three major industrial powers. They also describe the low-carbon living and lifestyles in Chinese society and points out the necessities of carbon reduction from a citizen level together with the NGOs' roles in terms of civic participation (Deng & Ye, 2014a). The four major pillars of low-carbon city infrastructures, namely, "transportation," "water," "energy" and "waste treatment" are discussed in (Shen et al., 2014).

Wang et al. (2014b) introduce China's first "Low-carbon City Index" developed by the Shanghai Advanced Research Institute, Chinese Academy of Sciences. They start by briefly reviewing the major urban sustainability index systems from the United Nations, the World Bank and some developed countries like the UK, US and Japan, showing the void of such systems in China for scientific monitoring and evaluating low-carbon cities. Followed by an in-depth description of methodological approaches, they further elaborate on the establishment of an indicator database, the initial and secondary selection of indicators, the specifications of finalized indicator sets and the initial analysis of results in evaluating domestic cities under the index. A ranking of 261 Chinese cities, found in the appendix, has received tremendous academic attention and media coverage since the publication of the book.

These works tackle different topics of low-carbon city regarding political framework, policies and regulations, case studies, strength and weakness analysis in regard to China's low-carbon urbanization practices from institutional, academic and industrial aspects. China's economic "wonders" have been well acknowledged by the world with both envy and criticism. It is becoming evident that more countries are becoming interested in the "Chinese recipes" of development and what China has to offer in the advent of the Asia Pacific era.

2.1.6 Smart Cities

The notion of a smart city is not novel (Shelton et al., 2015, p.2). It originated in the "new urbanism" trend in North America back in the 1980s, when the overall objective was to improve the urban environment and life though the promotion of communal ideas and limitation of urban sprawl (Vanolo, 2013). In the 90s, the U.S. government upgraded it into a "smart growth" trend that involved different stakeholders for boosting local real-estate markets meanwhile improving environmental conditions (Zelda, 2009). The term "intelligent city" was later brought up under the rise of the IT industry, where the focus was to connect the urban sphere with information and communication technologies (ICT) infrastructure

(Komninos, 2009; Zelda, 2009). Eventually, this terminology was converged and sometimes used interchangeably with the phrase “smart city”.

A more detailed review regarding smart-cites is presented in Chapter Five, in order to avoid redundancies and repetitiveness; I have briefly summarized the major works on smart cities. Caragliu et al. (2011); Nam, Taewoo and Pardo, Theresa A (2011); WU and YANG (2010) study the definitions and concept of “smart city” in a number of contexts. Chourabi et al. (2012) propose a framework to understand the many concepts of smart cities. Shapiro (2006) examines the quality of life under the smart city setting by empirical data analysis. Case studies of smart cities and applications are also studies with different focuses (Mahizhnan, 1999; Qiang, 2004). Cocchia (2014) review systematically the relevant works regarding smart cities and digital cities from 1993 to 2012. Giffinger and Gudrun (2010) developed a ranking mechanism for smart cites. Hollands (2008) also offers debates and critiques regarding the smart city phenomenon.

2.2 Prominent Urban Theories

There are three influential urban theories in the urban study discipline, namely, the “**postcolonial urban theory**”, the “**assessable theoretic approaches theory**” and the “**planetary urbanism theory**”, with each of these three system of knowledge attempting to understand the numerous topics related with cities, despite of their occasional distortions towards each other (Storper, 2016, p.3).Scott and Storper (2015) propose a possible theory to unify the diversity and disagreements in urban theories over the past 100 years or so, to “1) account for the genesis of cities in general; 2) capture the essence of cities as concrete social phenomena; and 3) make it possible to shed light on the observable empirical diversity of cities over time and space”(Storper, 2016, p.5).

Postcolonial urban theory, distilled mostly from the works of scholars of “the global north”, originated in cultural and historical studies. Thoughts under this theory tend to claim the equal distinctiveness and uniqueness of both the cities from the “global north and south”(Edensor & Jayne, 2012; Myers, 2014; Ong & Roy, 2011; Patel, 2014; Sheppard et al., 2013). Some major scholars of this school are notably against the application of urban theories of Europe and North America to the Global South (Storper, 2016, p.11).

Assemblage theory has gained main stage in urban studies of the past decades particularly in the social sciences (DeLanda, 2002; Latour, 2005). According to Storper (2016, p.20), this theory offers

- "an ontological view of the world conceived as a mass of rhizomatic networks or finely-grained relationships constituting the fundamental character of reality. These networks bind together unique human and non-human objectives with fluid, hybrid mosaics forming more or less temporarily stabilized systems of interconnections representing the current state of the observable world."

Planetary Urbanism emphasizes on the ever-blurring distinction between what used to be considered as urban areas from "geographic space", both conceptually and empirically (Brenner & Schmid, 2014). Despite the criticism from Storper (2016, p.25) (regarding their notion as "semantic confusion that ensues from applying the term 'urban' with all its familiar city-centric connotations…", comprehension of the convergence between geographical and societal boundaries can be linked to another theory that has recently influenced sustainable development theory – the Gaia theory.

In 1875, the Austrian geologist Eduard Suess proposed that all living creatures on the Earth constitute a sphere of life that he was the first to call the "biosphere". By the 1920s, the Russian geobiochemist Vladimir Vernadsky observed that the biosphere seems to be self-regulating in a way that promotes relative stability on Earth. Based on these early ideas, in the 1970s, the microbiologist Lynn Margulius and the atmospheric scientist James Lovelock proposed this Earth/life super-organism as "Gaia", after the Greek titan of Earth, as the evolving physical brain composed of the largely human-built infrastructures of cities and their support structures (Register, 2006, pp. 30-31).

Register (2006, pp.38-40) extends the analogy of "the city as organism" from a biosphere system point of view, stating that the city seems to have parts of "Skeletal system: for providing structural support – architecture, bridges, telephone poles … Sex organs of both sexes: for reproducing the system – colleges, design offices, environmental advocates, general voters, construction companies preparing to build more of the same or perhaps eco cities.” This has contributed to his interpretation of “eco-city” as we know it today.

2.3 Urban Sustainability Evaluation

There have been plentiful assessment methodologies for evaluating sustainable development over the years with different focuses. And frequently, indicators or indices are regarded as useful tools for policy making and public communication in terms of conveying information (Brenner & Schmid, 2014). Countries or corporations can adopt or customize indicators to summarize, focus and condense the complex or dynamic goals into a manageable amount of meaningful information. It is particularly useful for decision-makers to apply these sustainability assessment tools in order to assist them to determine the policies or actions that should be implemented to make society sustainable (Ness et al., 2007).

According to Singh et al., (2012), the two key methodologies for evaluating or assessing sustainability are monetary aggregation methods (MAM) and physical indicators, with the first primarily used by the economists and the second used mostly by scientist and researchers. Some examples of MAM include sustainable growth modeling, natural resource accounting and modeling, defining wealth and strong sustainability conditions, and other forms of economic frameworks.

Physical indicators such as sustainable development indicators or indices (SDI) are often developed or used to: 1) assess and evaluate the performance; 2) provide trends on improvement as well as warning information on declining trend for the various dimensions of sustainability i.e. economic, environmental and social aspect; 3) Provide information to decision makers to formulate strategies and communicate the achievements to the stakeholders (Ramachandran, 2000).

Ample indices of sustainability have been developed over the years. (KEI, 2005) have conducted a review of a total 41 sustainability indices, which can be categorized into twelve categories or themes (refer to Table 2-3). With regards to sustainability indices for cities, a total of seven individual indices were reviewed. They vary in locations, indicator quantity and dimensions, composition and weighting methods.

Table 2-3 List of Sustainability Evaluation Categories and Indicies

Categories (themes)	Indices (Contents)
1. Innovation, knowledge and technology indices	Summary Innovation Index Investment in the knowledge based economy Performance in the knowledge based economy Innovation Index National innovation capacity Information and communication technologies Technology Achievement Index General Indicator of Science & Technology Success of software process improvement
2. Development indices	Human Development Index Index of sustainable and economic welfare Relative intensity of regional problems in the Community
3. Market and economy based indices	Internal Market Index Business climate indicator European Labour Market Performance Composite Leading Indicators Genuine saving (GS) Economic Sentiment Indicator Green Net National Product
4. Eco-system based indices	Sustainability Performance Index Eco-Index Methodology Living Planet Index Ecological Footprint Fossil Fuel Sustainability Index
5. Composite sustainability performance indices for industries	Composite sustainable development index Compass Index of Sustainability Composite Sustainability Performance Index ITT Flygt Sustainability Index G Score method Sustainable Asset Management Zurich, Switzerland Dow Jones sustainability group indices, US Bovespa Corporate Sustainability Index
6. Product based sustainability indices	Life Cycle Index Ford of Europe’s Product Sustainability Index
7. Sustainability indices for cities	Urban sustainability index Sustainability index for Taipei City Development Index The Sustainability Cities Index Ecosistema Urbano Performance Index Sustainable Seattle: developing indicators of sustainable communities

	ISSI Index, Italy
8. Environmental indices for polices, nations and regions	Environment sustainable index Environment quality index Environmental sustainability index Concern about environmental problems Index of environmental friendliness Environmental policy performance indicator Environmental performance index Environmental vulnerability index Two “synthetic environmental indices”
9. Environment indices for industries	Eco-points Eco-compass Eco-indicator 99 Environment assessment for cleaner production technologies COMPLIMENT – environment performance index for industries
10. Social and quality of life based indices	Gender empowerment measure Physical quality of life index Well-being assessment National health care system performance Overall health system attainment Index for sustainable society
11. Energy based indices	Sustainable assessment tool for energy system Energy indicators for tracking sustainability in developed countries
12. Ratings	Benchmarking US petroleum refineries, the environmental defense fund, US NGO ECCO-CGECK Index, Environmental risk rating Investor responsibility research centre Council on economic priorities Oeko Sar Fund Storebrand Scudder environmental value fund Innovest strategies value advisors OEKOM environment rating Jupiter income trust funds FTSF good index

Compiled by the author based on (Singh et al., 2012)

However, when it comes the construction or development of such indices, there are not commonly followed principles or approach, but rather very general guidelines. According to Dewan (2006), there are two major steps for developing a composite index: 1) policy goals have to be clearly defined; 2) the components and sub-components than need to be determined based on theory, empirical analysis, pragmatism on intuitive appeal or some combination of them. Furthermore, different stages of indices development or composition require appropriate selections of methods/tool/techniques, which may result in issues such as uncertainty in data selection, erroneous data, normalization, standardization, aggregation and weighting (Dewan, 2006).

It is of great importance to critically understand and analyze the impacts of new sustainable urban development models and frameworks in specific context, and to create more effective approaches to achieve positive outcomes and evaluation method or approaches for societies of different origins (Singh et al., 2012, p. 282).

3 ECO-CITY DEVELOPMENT IN CHINA: INTERNATIONAL PERSPECTIVE AND COMPARISON

China's growing international dominance and influence has been witnessed and acknowledged across the world. But its annual GDP growth contributed by rapid urbanization and industrialization comes with severe environmental costs, especially in urban areas. Determined not to repeat some industrialized countries' mistake of "treatment of environment comes after the development of economy", China has set up a number of laws and regulations to safeguard the sustainable development in urban areas. Eco-city development is one of the early national attempts in curbing the derailed urbanization trajectory.

This chapter[6] reviews the urban policy frameworks and current practices in China's major cities, with the comparative introductions between the past standards of Chinese eco-cities and that of the current, on both national and provincial levels. Furthermore, this chapter compares the existing eco-city standards with international acknowledged examples in Japan and Germany by analyzing the key indicators from selected eco-city case studies.

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[6] Based on this chapter, a journal paper has been published as Zou, X. & Li, Y. (2014). "How 'Eco' are China's Eco-Cities: An International Perspective", *International Review for Spatial Planning and Sustainable Development*, 2(3), p18-30.

3.1 Chapter Introduction

3.1.1 Eco-city origin and concepts

As a common practice in the scientific communities, it is of great importance to acknowledge the origin of a certain concept. When it comes to the term “eco-city”, the American urban designer Richard Register is the creator of this concept, especially since his publication of the renowned book Eco-city Berkeley (Register, 1987). However, from a timeline point of view, the concept of “eco-city” had been brought up earlier. Many scholars believe the first concept of eco-city was brought up in the United Nations Educational, Scientific Organization’s (UNESCO) “Man and Biosphere” (MAB) Program (Xie et al., 2010).

The MAB project was established to promote the “improvement of the relationships between people and their environment globally” via interdisciplinary research agendas, encompassing various sub-programs with different focuses (UNESCO MAB Website, 2013[7]). It was the former Soviet Union scientist Yanitsky who first mentioned the word “eco-city” in the MAB conference paper of UNESCO in 1981, where he promoted the creation of “eco-city” as “a human settlement of the future in which social and ecological processes are combined in the best possible fashion”（Yanitsky, 1981）.

Despite the literal appearance of the Eco-city concept in the early 1980s, a number of precursory concepts like “Garden City, “New Town” or “Techno-City” amongst others had laid the foundations or contributed to the development of the early concept (Joss & Tomozeiu, 2013; Roseland, 1997).

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[7] http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/man-and-biosphere-programme/

3.1.2 Definitions of eco-city

Despite the quantity of eco-city projects, there is not yet a universally agreed-upon definition but different concepts, interpretations addressing various angles or from different perspectives of eco-city concepts. For instance, Yanitsky (1981) articulates that an eco-city is an ideal habitat with a benign ecological circulation in which technology and nature fully merge; human creativity and productivity reach a maximum level; the residents' health and environmental quality are well protected; and energy, materials, and information are efficiently used. Register (1987) regards an eco-city as an ecologically healthy city in which the object of ensuring the health and vigor of man and nature reasonable guides human activities. Engwicht, the Australian community activist advocates an eco-city is where people can move via foot, bicycles and mass transit and interact freely without fear of traffic and toxins. Chinese scholars like Ma and Wang (1984) consider an eco-city as a stable, harmonious, and sustainable complex ecosystem that makes possible "all-win" development among social, economic, and environmental factors; full fusion of technology and nature; maximal motivation of human creativity; increasingly improved urban civilization; and a clean and comfortable urban environment summarized by Su et al. (2013). Engwicht (1993) defines eco-city as "an invention for maximizing exchange and minimizing travel" and "in eco-city people can move via foot, bicycles and mass transit and interact feely without fear of traffic and toxins". An in-depth discussion of eco-city origin and its dimensions is given by Roseland (1997), where he connects the dots of eco-city developments by exploring its conceptual evolutions from an array of sustainable development contexts.

In China, many scholars have also offered their own perceptions, such as Wang (2000) considers an eco-city to be an administrative unit that consists of high economic productions, high ecological efficiency, responsive and harmonious social cultures. Huang (1989) proposes that eco-cities should build upon ecological principles, integrate social-economical-natural systems, and apply inter-disciplinary concepts to develop sustainable, efficient and recycling human residential areas. Others scholars like Shen (1998) consider an eco-city to be an integrated system of highly developed economy, prosperous society where technology and nature are fully converged, human creativity and productivity fully extended. Huang and Yang (2001) reckons that eco-city is a subsystem under the global regional eco-system, which is based on principles like natural harmony, social justice, high economic efficiency (Qiu, 2010).

3.2 Development of the Eco-City

3.2.1 Eco-city development

In a broader sense, this idea of “eco-city” can be dated back to ancient Greek and Egypt, when major location for city construction was greatly influenced by its surrounding environment. In 1898, the British thinker Howard’s “Garden City” theory has been considered as the root for eco-city in contemporary time (Fu et al., 2011). The literal appearance of “eco-city” occurred in the early 1980s, promoted by UNESCO’s MAB project, and scientists and activities like Yanitsky and Register all came up with rather theoretic frameworks for eco-city developments with rather few acknowledged examples. From early 1990s to 2000, especially after the United Nations’ “Earth Summit” (Rio de Janeiro, 1992) when the “Agenda 21” was initiated, translating those concepts into the first wave of practical eco-cities like Curitiba (Brazil), Waitakere (New Zealand), Schwabach (Germany) among others (refer to Figure 3-1). Since then, the booming of eco-city and such initiatives have been seen worldwide, by the year 2011, an eco-city global survey conducted by Joss et al. (2011), a total of 174 profiled eco-cities have been subjected in their survey globally, and in previous 2009 survey, this number was 79.

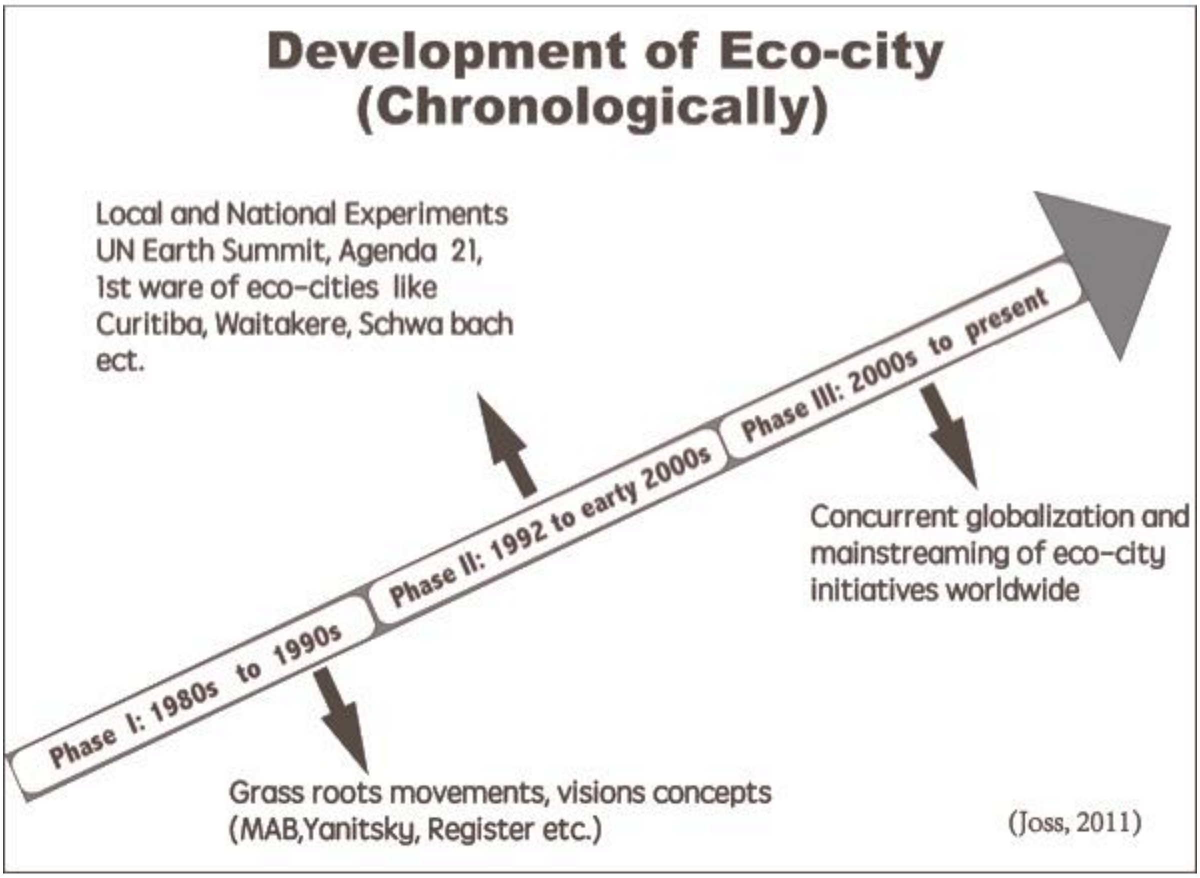

Figure 3-1 Chronological Development of Eco-city.

Illustrated by the author based on Joss (2011)

From a conceptual point of view, the concept of eco-city has been concurrently developing and evolving according to Joss et al. (2011) and three conceptual perspectives have been identified by him as is shown in Figure 3-1. The first one is what he entitles "'normative' perspective", when the eco-city development is driven by various concepts, ideologies and political demands among others. This perspective, to some extent, coincides with the first development phase of eco-city, when MAB program promoted the interdisciplinary studies between human and biosphere, and people from different background tried to offer their perspectives of defining and developing eco-cities. The second perspective is what Joss calls "'regulatory' perspective": it is when the concept of eco-city has been incrementally standardized by the major sustainable frameworks of the develop phase II, such as Brundtland Report, Rio Earth Summit, and Agenda 21. The first wave of eco-cities in practice like Curitiba (Brazil), Waitakere (New Zealand), Schwabach (Germany) etc. are the results of implementations of these standardized concepts. The third

“’innovation’ perspective”, mainly associated with the Phase III of eco-city development, is when eco-city concept is integrated with innovative concepts from socio-technological aspect, business development and culture branding. “Decarbonization” has thusly become the defining the feature of developing eco-cities worldwide.

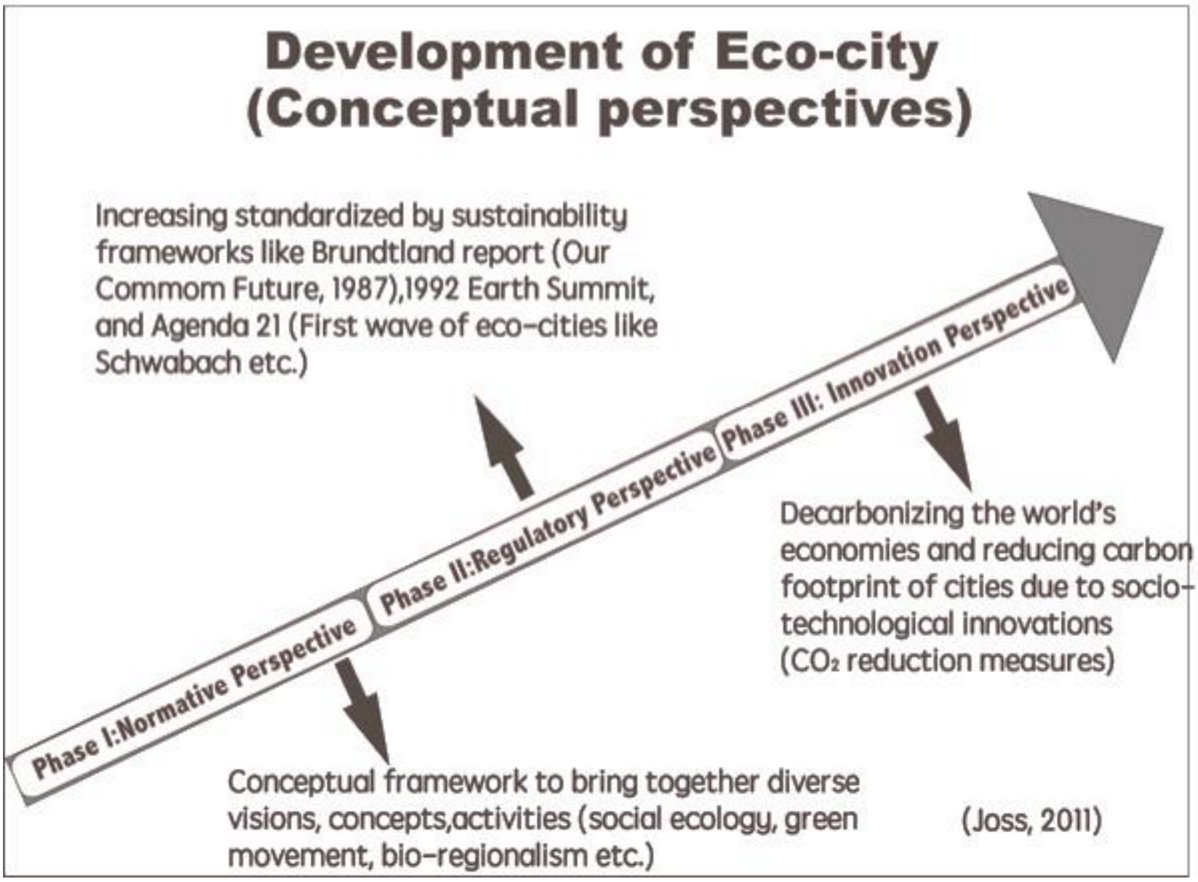

Figure 3-2 Conceptual Perspectives of Eco-City Development.

Illustrated by the author based on Joss (2011)

From a country specific point of view, I also find the eco-city development in China to be in synchrony with the development phases concluded by Joss based on the extensive reviews of China’s country-level political framework of eco-cities (refer to Figure 3-3). In the year 1986, Yichuan City (Jiangxi Province) brought up the goal of developing the first “eco-city” in China, which reflects the local government’s effort to tackle the local environmental and ecological challenges caused by urbanization.

In the early 1990s, the former Chinese Ministry of Construction (MoC) enacted a national framework of "Garden City", focusing on the landscape and green space urban developments. This is the first national scale attempt to redirect the urban development path into a more sustainable trajectory. In 2004, the successor of MoC, the Ministry of Housing Rural and Urban Development (MHURD) upgraded this framework into "Eco-Garden City", addressing, with more pressing and comprehensive indicators, the related urban developments.

In the same year, the Ministry of Environment Protection (MEP) came up with a national framework of Eco-cities (containing three levels, county, city and province), with more standardized concepts and indicators for urban development, coinciding with the Phase II chronologically and conceptually. Then in 2008, the National Development and Reform Commission (NDRC) initiated the nation wide frenzy of "Low Carbon City" developments, in an attempt to realize the CO2 emission reduction target set in the 11th Five Year Plan. The focus since then has been on decarbonization in urban development, which mirrors the Phase III of Joss' observation.

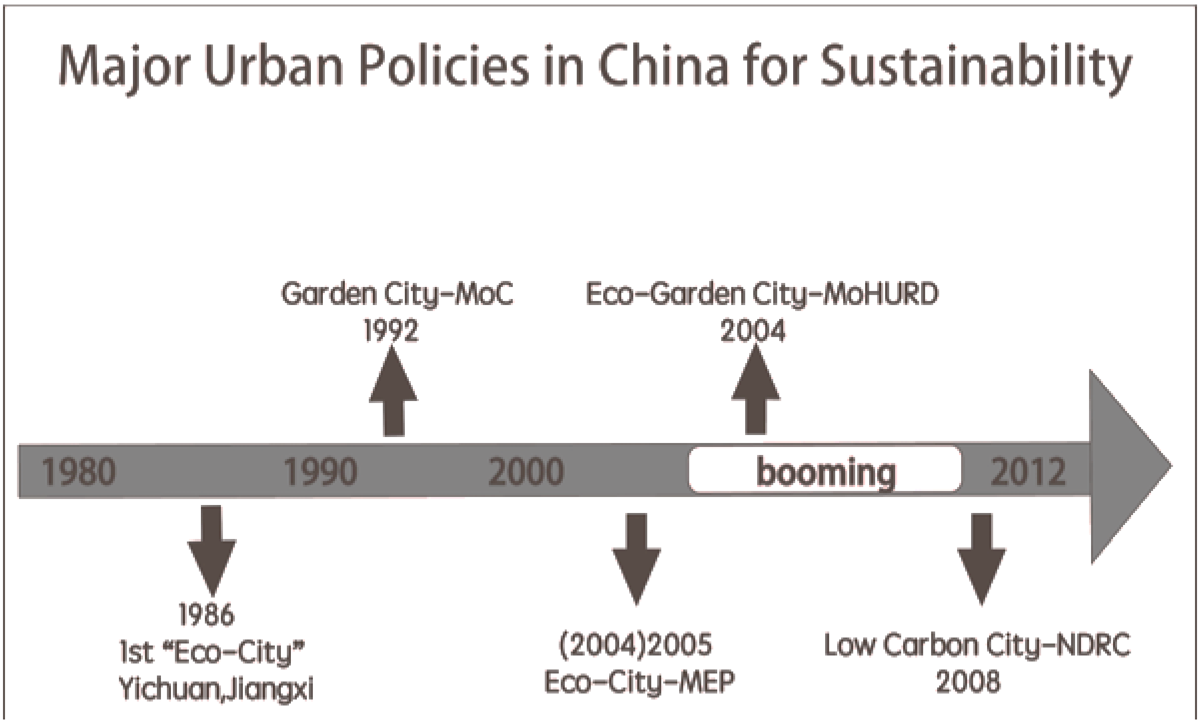

Figure 3-3 Eco-cities framework development in China.

Complied d by the author based on governmental websites

3.3 Eco-cities Development in China

China as the world's largest country in population and currently 2nd largest country in GDP has also been experiencing an unprecedented urbanization rate. In 2011, the urban population had surpassed the rural population for the first time in Chinese history, reaching 690 million. The urban population rate was 17.92 % in 1978 and is expected to reach 70% by 2050 (Chinese Soceity for Urban Studies, 2012). The fast population growth and rapid urbanization rate have brought severe ecological & environmental challenges, public health threats and life quality concerns. To combat these issues, the Chinese government has taken bold and ambitious plans and goals to developing eco-cities initiatives across China. According to the Chinese Society for Urban Studies 2011, over 230 cities have or will have eco-cities projects of different levels, accounting for 80.1% of the 287 domestically.

In terms of eco-cities frameworks, China's Ministry of Environmental Protection (MEP) and Ministry of Housing and Urban-Rural Development (MHURD) have been actively engaging in the establishment of national standards for eco-cities in pursuit of domestic urban environmental agenda. However, the two organizations have different focuses, for example, MHURD focuses on mainly on urban infrastructure construction while MEP focuses on a broader scope such as targets on energy and resource use efficiency (World Bank, 2009). The National Development and Reform Commission (NDRC) has initiated the Low-Carbon City since of 2008, but there is only general development principle without specific action plans nor assessment indicators, resulting in differentiated developments for eco-cities in China.

From a timeline point of view, the very early "eco-city" development goal was brought up in 1986 at Yichun City, Jiangxi Province in China. The real booming of eco-cities started since 2003 – 2004, followed by the concept of "low-carbon city" brought up in 2008, which has been widely spread ever since (Qiu, 2010). Some of those cities apply the standards of MEP and MHURD to developing their small or medium sized eco-cities, with samples such as Rongcheng Eco-city, to large cities like Shenzhen. And the trend of employing international expertise and partnership also manifested in the recent years such as the Sino-United Kingdom Chongming Dongtan Eco-City, Sino-Sweden Tangshan Caofeidian International Eco-city, and the Sino-Singapore Tianjin Eco-City (SSTEC) etc.

3.3.1 Eco-city framework in China

According to the regulatory bodies and standards, Chinese eco-cities can be classified into three major categories. The first two categories have been defined by two ministries; “Eco-garden City” by MHURD and “Eco-city” by MEP. Though the NDRC has been advocating “Low Carbon Cities” on a national scale, there is not yet a set of official indicators for assessment in place. The third category is composed of international joint venture projects like Sino-Singapore Eco-City, Sino-Sweden Caofeidian Eco-City etc. that follow their own master plans and development principles, resulting also in differed indicator systems among themselves.

Ministry of Housing Urban-Rural Development

In 1992, the Ministry of Construction (MoC), predecessor of MHURD, initiated the “National Garden City” program. To implement the Strategy of Sustainable Development and lead the eco-environmental development of cities, MoC initiated the “Eco-Garden City” program based on the previous “National Garden City” program. Qingdao, Yangzhou, Nanjing, Hangzhou, Weihai, Suzhou, Shaoxing, Guilin, Changshu, Kunshan, Jincheng, and Zhangjiagang were among the first demonstration cities. By the end of 2010, MHURD, successor of MoC, had issued 13 releases declaring a total of 184 National Garden Cities designated through the program (Zhou et al., 2012).

To qualify for an Eco-Garden City, one must first be designated as a National Garden City, which requires the city to meet a set of additional standards with most of them quantitative measurement that the appraisal standards required of only Garden Cities. MHURD’s[8] indicator system contains 19 primary indicators of three categories, namely, urban ecological environment, urban living environment, and urban infrastructure.

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[8] All the MHURD regulations are available at http://www.MHURD.gov.cn/

Ministry of Environmental Protection

The other guideline of eco-cities development in China is provided by MEP. In 2003, MEP initiated a program to establish eco-counties, eco-cities, and eco-regions on a national scale. And following that initiative, MEP introduced a set of assessment criteria entitled "National Ecological County, Ecological City Establishment Assessment (Trial)" for evaluating the participating parties. In 2005, revisions on the criteria were made based on the feedbacks from the previous implementation, which was officially released in December 2007 (Zhou et al., 2012).

The official document contains three major parts of eco-counties, co-cities and co-provinces, following a similar methodology, definition, basic requirement, indicators and explanations. The indicators consist of three sections, namely, economic development, environmental protection, and social progress. Under each section, there are a number of indicators addressing different items of the relative aspect. For the Eco-Country level, there are 36 indicators, 28 for Eco-cities, and 22 indicators for Eco-Provinces (MEP, 2007). Up to July 201, there had been 38 cities entitled with "Eco-City (County)" according to MEP's assessment in 11 provinces nation-wide (refer to Table 3-1).

National Development and Reform Commission

NDRC is China's central body for economic development and coordination, and it is also the frontier for directing the domestic climate change combating policies. As part of the fulfillment of China's Green House Gas (GSG) emission targets, NDRC has been greatly promoting the green economy concept with carbon emission reduction its key component. As a result, developing Low-Carbon City has thusly been promoted by NDRC in China. However, the specific national assessment indicators are still undergoing completion, and the pioneer project cities or regions are mandated to establish their own Low-Carbon City development plan according to their local realities and conditions.

Table 3-1 List of Entitled Cities of Different Standards by July 2011

Province	**MEP Eco-City**	**MHURD Eco-Garden City**	**NDRC Low-Carbon Demonstration City**
Anhui	Huoshan		
Beijing	Miyun, Yanqing		
Chongqing			Chongqing
Fujian			Xiamen
Guangdong	Shenzhen Tantian District, Zhongshan, Shenzhen Futian District, Banshan District		Shenzhen
Guangxi		Guilin	
Guizhou			Guiyang
Hebei			Baoding
Jiangsu	Zhangjigang, Changshu, Kunshan, Jiangyin, Taicang, Yixing, Wuxi Binhai, Xishan District, Guishan District, Wujiang, Wuzhou Wuzhong District, Gaochun, Nanjing Hiangning District, Jintan, Changzhou Wujin District, Hai’an	Ynagzhou, Nanjing, Suzhou, Zhangjiagang, Kunshan, Changshu	
Jiangxi			Nanchang
Liaoning	Shenyang Donglling District, Shenhei New District		
Shaanxi	Xi’an Saba Ecodistrict		
Shangdong	Rongcheng	Qingdao, Weihai	
Shanghai	Minhang District		
Shangxi		Jincheng	
Sichuan	Shuangliu, Chengdu Wenjiang District		
Tianjin	Xiqing District		Tianjin
Zhejiang	Anjie, Yiwu, Lin’an, Tonglu, Pan’an, Kaihua		Tianjin
Cross-program cities	Zhangjiagang, Nanjing, and Kunshan participate in both the MEO and MHURD programs, Hangzhou participate in both the MHURD and NDRC programs.		

Source: (Zhou et al., 2012), MEP, MHURD, NDRC

Only a handful of cities are engaged in more than one program from the national standards as is in shown in Table 3-1. And no city so far has participated in all the three national programs, which indicates that their own frameworks and assessment can be quite varied from each other, resulting in few over-lapping cities.

Joint-Venture Eco-Cities Program

These eco-cities feature in the cooperation between China and other parties from the international communities. Such projects usually build new cities in the designated area from scratch, following completely the master plan particular designed for their eco-city development goals. The most famous examples are the Sino-Singapore Tianjin Eco-City and the Caofeidian Eco-City. These eco-cities have their own standards and indicators that fully address their local characteristics and emphasis. Most of them are demonstrative in nature for future urban planning rather than meeting the practical urbanization demands.

3.3.2 The Eco-cities indicator systems in China

To assess the attainment levels of the eco-cities, the establishment of indicator systems is very necessary. However, due to the diversity of eco-city standards in policies, principles and practices, a number of indicator systems have been proposed by researchers and scholars to define their own scopes, targets and assessments. Table 3-2 shows the 11 major indicator systems practiced in China, among which, the Chinese Academy of Sciences (CAS) has come up with the most amount of 146 indicators pertaining to support for the ecosystem, development, environment, society and intelligence security. The Caofeidian eco-city indicator system, developed by Sweden’s Sweco in cooperation with Tsinghua Urban Planning Institute, contains 141 indicators related to city function, building the building industry, traffic and transportation, energy, waste, water, landscape and public spaces. The Tianjin Sino-Singapore eco-city has 22 controlled indicators and 4 directive indicators related to coordination with regional policy, the natural ecosystem, society and culture, and regional economics (Zhou et al., 2012).

Table 3-2 Major Indicator Systems in China

Indicator System	NO. of Indicators	Source
Chinese Society for Urban Studies	45	Chinese Society for Urban Studies, 2011
China City Sustainable Development Indicators	146	Chinese Academy of Science
CAS (Research Center for Eco-Environmental Sciences)	25	Wu, Wang et. al, 2005
Renmin Univ. & Tsinghua Univ.	5	Zhang, Wen et. al, 2008
MoC/MHURD Eco-Carden City	19	MHURD, 2004
MEP Eco-City	22	MEP, 2007
Tianji Eco-City	26	Tianjin City
Caofeidian Eco-City	141	Caifeidian City
Turpan New District	36	Turpan City
Guiyang Eco-Civilization City	33	Guiyang City, 2008

Source: (Zhou et al., 2012)

Eight categories have been considered as key categories – energy, water, air, waste, transport, economy, land use, and social aspects, which encompass over 130 indicators from the 11 indicator systems of China. The following table shows the categories covered in each of 11 indicator systems. As seen in Table 3.3, most indicator systems include air (9) energy (8), water (8), land use (8) and waste (7), while transport (5) and economy (5) are less commonly included. The social aspect is included only by four systems out of these 11 selected indicator systems. And the Guiyang Eco-Civilization City is the only one who has included all these 8 aspects for indicators. All the other systems have their own different focuses.

Table 3-3 Categories Covered in Indicator Systems

Category	**Energy**	**Waste**	**Air**	**Waste**	**Transport**	**Economy**	**Land Use**	**Social Aspects**
Chinese Society for urban Studies	x	x	x	x	x	x	x	x
CAS/China City Sustainable Development Indicators	x	x	x			x	x	
CASS(Zhuang, Pan,and Zhu,2011.)	x							
RUC(Zhang ,Wen et al.2008)						x		x
CAS (Wu and Wang ,2005)	x	x	x	x		x	x	x
MoC (MHURD Eco-Garden City)		x	x	x	x		x	
SEPA/MEP Ecological Province/City/ County	x	x	x	x			x	
Tianjin Eco City	x	x	x	x	x		x	
Caofeidian	x	x	x	x	x		x	
Turpan New District			x					
Guiyang Eco-Civilization City	x	x	x	x	x	x	x	x
Totals	8	8	9	7	5	5	8	4

Source: (Zhou et al., 2012)

When it comes to each major category of these indicators, water has the largest number of 33 sub indicators, which reflects the importance of water in the Chinese eco-city development. According to Zhou et al. (2012), the indicators for carbon emissions are integrated into energy category. Only the systems for Tianjin Eco-City and Caofeidian Eco-City include carbon intensity indicators. Even though carbon productivity and carbon emission per capita or per GDP are included in other indicator systems, they are compared with national standards, without proposing any city-specific criteria. Despite the commonness of air in the eight systems, it has the least number of 9 indicators, the same as transport.

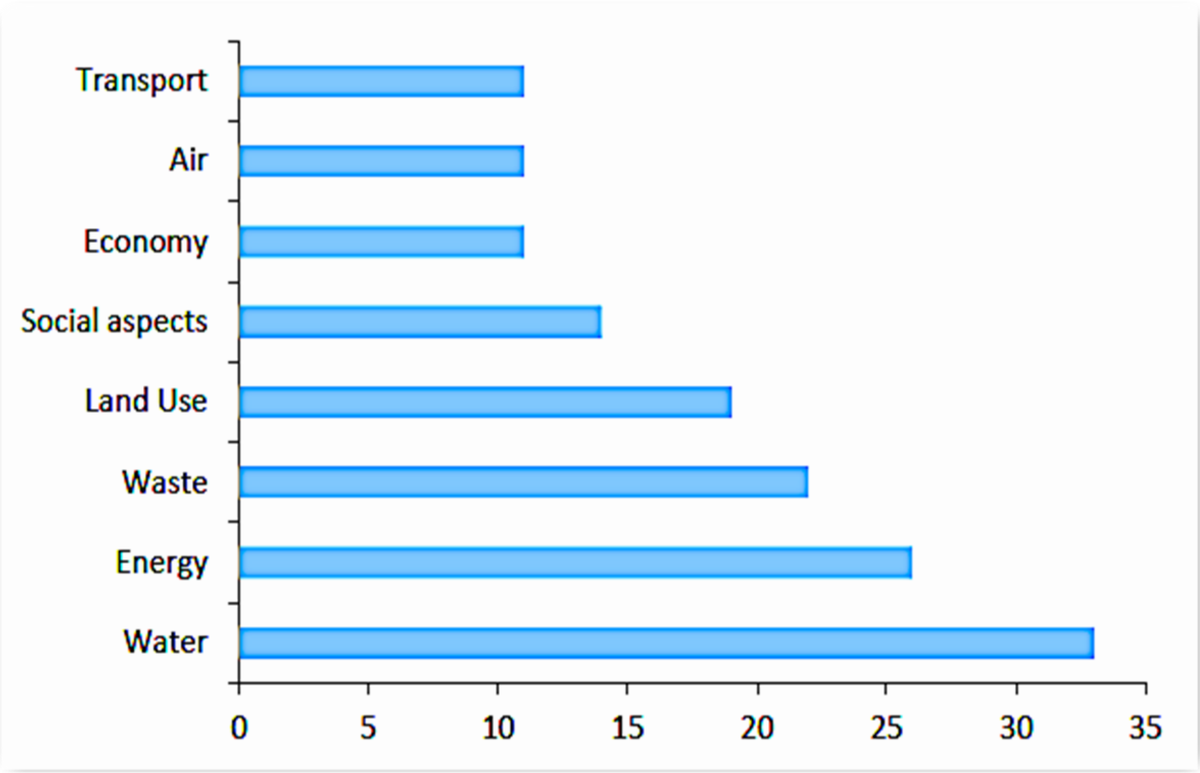

Figure 3-4 Numbers of Indicators by Major Category.

Source:(Zhou et al., 2012)

To sum it up, in China, there are a number of different indicator systems for eco-cities development established by government entities, academic institutes, and researchers, with each of them addressing their perspective development needs. There is not yet an integrated, comprehensive national standard or guidelines in China, but the major categories of indicators were agreed upon and included by most of them. The commonalities of categories do not manifest a direction portion in indicator quantities; for example, air category is the most common in the 8 selected systems but only has 9 indicators. But major concerns of categories tend to have more indicators in eco-cities development, such as water, energy, waste, land use etc. Another point is that carbon related indicators are either barely mentioned or not enlisted as a major category but integrated into others.

Great variety is seen in a number of international indicators from selection criteria, weighting, benchmark and application levels. To have an overall understanding of the current status quo for the international indicator systems requires extensive amount of literature reviews and efforts. Zhou and Williams (2013) have conducted a study of analysing 16 sets carefully selected indicator systems worldwide to summarize their common characteristics, review their threshold issues, aggregation in ranking schemes, benchmarks for definition as well as the commonalities among different systems, based upon which, the comparative analysis is conducted (refer to Table 3-4).

Table 3-4 Summary of Reviewed Indicator Systems

Type	**Reference**	**Object of Analysis**	**Number of Indicators and Categories**
City Rankings	EIU2011	22 largest and most important cities in Asia	29 in 8 categories
	PriceWaterhouse Cooper 2011	26 large cities of financial and political importance worldwide	4 in 1 category(only Sustainability category used.Total of 66 in 10 categories.)
	Forum for the Future 2010	UK's 20 largest cities	11 indicators grouped in 3 categories.
	ACF 2011	Australia's 20 largest cities	15 grouped in 3 categories
	Kalenzig et al. 2007	U.S's 50 largest cities	15 in 15 categories
	Corporate Knights 2011	Canada's 17 overall most populous cities and most popular city in each province	28 in 5 categories
	EU Green Capitals Program 2011	Applicant cities in Europe with population >200k	71 in 10 categories
	MONET 2009	17 cities in Switzerland	31 in 3 categories
Ranking Provincials	Esty et al.2011.	All Chinese Provinces	33 in 12 categories
	GCI 2007	Core and Secondary indicators of Sustainability of Urban areas to facilitate standardized policy practice sharing among member cities	77,grouped in 20 themes
	ESMAP 2012	Tool to allow city leaders benchmark energy efficiency in their cities against similar cities to	28 in 6 categories

Non-ranking City-level		Indicate best practice policies and strategies	
	Heine et al.2006	Indicators chosen to establish a framework process to improve Victoria state citizen engagement ,community planning and evidence based policy making	21,in 1 category (Only Sustainable built and Nature environment category used, out of 75 in 5 categories)
	Sustainable Seattle n.d.	Indicators used to empower Seattle Sustainability advocates and practitioners to take effective action independently and together.	99 in 22 categories (goals)
	Boston indicators Project 2012	Project aims to democratize access to information ,foster informed public discourse,track process on shared civil goals ,and report on change.	29 in 1 category (Only Sustainability Category used here ,out of a total of 185 in 10 categories)
	Hakkinen 2007	EU environmental program priorities regarding climate change ,nature and bio-diversity ,high environmental quality and health ,and sustainable resource use and waste management.	45 in 5 categories
	Xiao Xue and Woetzel,2010	Tool to measure relative performance over time at city level in Chinese cities that have been the focus of sustainable development efforts.	18 in 5 categories

Source: (Zhou & Williams, 2013)

Table 3-4 illustrates the 16 international indicator systems enlisted. Nine of them are ranking systems, which include on the average 26 indicators, and 7 are non-ranking ones including an average of 45 indicators. There is a noticeable difference in amount between the ranking systems' indicators than the non-ranking ones, from which we can assume that the less indicators there are, the easier it can be for ranking. However, the exception is from the "EU Green Capital Program 2001" which is a ranking system with as many as 71 indicators in 10 categories.

Amongst these systems, 8 primary categories have been identified as the primary categories that are common to most of the international systems. However when it comes to secondary category indicators, there is a significantly less agreement in their adaptations. Amongst the 16 international systems that were studied by Zhou & Williams (2013), only ten secondary indicators were common to more than 2 systems. The most two common indicators, "total water consumption in liters/capital/day" and "CO2 emissions in tons/capital/day" were found in 7 systems. Two secondary indicators were found in 5 systems, one was found in 4 systems, and five in 3 systems. This phenomena indicates that among the international communities, consensus can be reached upon the general criteria for assessment, but the specific indicators are greatly varied due to their respective policies focuses, development mythologies, regional features among many other reasons (see Table 3-5).

To better have comparative view of the Chinese systems with the International ones in terms of their indicator categories, I have included the primary and secondary indicator categories from the 11 major eco-cities guidelines available within China, to compare with the same categories from the international ones, and come up with the following table (refer to Table 3-5).

It can be observed that the primary categories from the two sets are almost identical to each other, which indicates that the macro aspects of assessing the eco-cities internationally can be universally agreed upon. For secondary categories, except for "Water", where China has more secondary categories than the International ones, the rest of them are more or less smaller than the International ones in terms of quantity. One big gap between the two sets is in the "Energy" category, where there are only 3 secondary categories in China, 8 for the international ones. But content wise, great disparity is seen for the secondary level of indicators despite of the overlapping ones.

Table 3-5 Primary and Secondary Categories of Chinese Indicator Systems and International Indicator Systems

Chinese Indicator Systems		**International Indicator Systems**	
Secondary Categories	Primary Categories		Secondary Categories
Penetration of running water	Water	Water Quality, Availability, and Treatment	Water Consumption Intensity
Utilization of reclaimed water			Water Quality
Net loss of natural wetlands			Waste water Treatment Connection and Rates
Fresh water consumption per unit of industrial added value			Water Availability by Carrying Capacity
Effective utilization coefficient of			Access to Water

irrigation water			
Daily water consumption per capita			Other; Water Policy Achievements
Utilization rate of non-conventional water resources			
Surface/near shore water quality			
Compliance rate for quality of city pipeline water			
Urban sewage treatment rate			
Energy consumption per GDP	Energy	Energy and Climate	Carbon Intensity
Carbon emission per GDP			Energy Intensity
Renewable Energy utilization rate			Building Energy Use/Carbon
			Renewable Energy Use/Carbon
			Transport Energy/Carbon
			Energy and Climate Change Policy
			Split of Total Energy / Carbon Within All Sectors; Energy Security; Industry Energy/ Carbon
Quality of air environment	Air	Air Quality	PM10 Concentrations
Days of air pollution index ≤100			Nox Concentrations and Total Emissions
Regional air quality			Other Types of Emissions; Index of Multiple Air Pollutant Concentrations; Exceedance of Air Quality Benchmarks; SO2 Concentrations; O3 Concentrations and Emissions; Other
Intensity of discharge of major pollutants (COD / SO2)			
Daily waste per capita	Waste	Waste	Waste Generation Intensity
Hazardous waste and garbage (harmless) treatment rate			Waste Treatment - Recycling
Industrial solid waste utilization and treatment			Waste Treatment - Diversion from Landfill; All Treatment of

Harmless treatment rate of garbage			Total by Proportion; Waste Treatment - Landfill Disposal; Waste Capture Rates; Other Treatment; Other Waste Indicators
Rate of waste recycling			
Percentage of green transportation	Transportation	Transportation	Transportation Facilities and Infrastructure
			Model Use
			Accessibility of Transport Options
			Policies; Other; Air Transport
Average GDP per capita (developed regions & less developed regions)	Economy	Economic Health	Employment
			Green or Innovative Sectors
			Cost of Living
			Other
			GDP and Income
			Debt, Savings, and Investment Levels; Government Financing; Businesses with Environmental Management Systems; Resource Productivity
Percentage of protected area	Land Use	Land Use and Urban Form	Public Green Space
Average per-capita public green land			Population Density
Green coverage in built-up area			Biodiversity
Per-capita public green space in built-up area			Other; Protected Lands; Built Up Area Forestry; Policies; Smart Growth Index; Ecological Footprint; Agricultural Lands
Rate of green land in built-up area			
Public satisfaction with the environment	Social Aspects	Demographics & Social Health	Health
Entrance rate for higher education			Education

			Public, NGO, and Academic Participation
			Aesthetics
			City Leadership in Collaborative Efforts
			Risks and Crime; Equity; Other; Noise

Source: Compiled based on MEP, MHURD, Tianjin Eco-City; (Zhou et al., 2012)

From the qualitative analysis of the two groups of indicator systems from China and the International best practices, no definite results can be derived but two indications. Firstly, the general aspects of assessment can be universal, which is suggested by the 8 primary indicators shared-by both international systems and Chinese systems. Secondly, the overlapping and variation of secondary indicators suggests the multiversity of specific indicators from a worldwide perspective, which could be the result of different development needs, political restraints, and methodological approaches among many factors.

Based on the comparison of these two groups of eco-cities assessment indicator systems, it is less convincing for offering definitive answers to the research question proposed by this paper. Thus, a quantitative comparison of three specific sets of indicators from China, Germany and Japan are conducted to search for possible results.

3.4 Comparison for China's Eco-cities with Japan's Cases

This section aims to analyze the quality of Chinese Eco-cities in comparison with those in other counties. An effective means to have observable evaluating results is to have quantitative analysis of the selected subjects. In this case, I design to choose one best-practiced Chinese eco-city to compare with eco-cities from cases in Japan. However, due to the lack of consensus on the currently available best case example of Chinese eco-cities, and the potential workload to evaluate and select one with public creditability, after consideration, I have decided to select a hypothetical eco-city under the assumption that it meets all the eco-city standards (thresholds) set up by MEP as baseline. The city of Suzhou was chosen as a best practice case of Chinese Eco-city. For the international comparison, the Japanese city of Kitakyushu was chosen.

3.4.1 Selection of case study cities

Two internationally acknowledged eco-cities are chosen from the two countries, namely, the City of Kitakyushu in Japan and the Suzhou City in China. The City of Kitakyushu, with a population of close to one million, is famous for her rigorous environmental engagement from the municipal government, business sectors, research institutes as well as the local communities and citizens. This former "notoriously" polluted industrial center in the Kyushu region of Japan has been transformed into a recycling-oriented, resource efficient eco-friendly industrial zone with high life quality standards. It has been accredited both by the national government and international organizations including the UN and OCED.

The Chinese city of Suzhou is a prefecture level municipality with a population of 5.45 million and 2,743 km2 of territory coverage (Suzhou Statistical Yearbook 2014[9]). It is located in the south part of Jiangsu Province neighboring Shanghai City. It is ranked one of the most developed and richest cities in China with a GDP of 20,000 USD per capita in 2014 (Li & Qiu, 2015). It is highly regarded and praised for its efforts on preserving the local culture, promoting economic development and protecting the environment from different aspects. And it has been acknowledged by many "Eco" titles by national government entities such as MoE and MHURD (Li & Qiu, 2015).

3.4.2 Data collections

The primary data of eco-cities indicators for the two case study cities are taken from their respective regulatory bodies and official websites, sometimes the contents are in

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[9] http://www.sztjj.gov.cn/tjnj/2014/indexeh.htm

another language, the translation is also adapted mostly from the official designated translations or the public recognized ones. Considerable amount of secondary analysis of the primary data is also collected for consideration or comparison criteria selections.

3.4.3 Comparison criteria and applied method

The MEP's eco-city standards consist of 19 indicators under three categories, namely, "Economic Development", "Environmental Protection" and "Social Development". I have selected a few key indicators as the baseline scenario for the "ideal" Chinese eco-city, which is then compared with the corresponding indicator targets or thresholds of the City of Kitakyushu and the City of Suzhou.

However due to the lack of creditable verification and methodological approaches for MEP's indicators standards, I have not been able to include all the 19 indicators but only the ones with most confidence in comparison and data availability. More weight is given to the environmental assessing indicators for selection, and priority of selections have also based on their relevance and data availability. In many cases, for indicators such as "energy and water consumption per unit of GDP" and a number of others with different units of measurement, necessary conversions and recalculations are performed to unify the differences in units.

3.5 Eco-city comparison between China and Japan

3.5.1 Economic aspect

For the economic aspect, the MEP framework has 5 indicators under economic category and they are used as the baseline for comparison with Kitakyushu in Japan and Hamburg in Germany as is shown in Table 3-6.

Table 3-6 Comparisons of Economic Indicators for ‘Eco-Cities’

Economic Development					
NO.	**Indicators**	**Unit**	**Eco-City (Baseline)**	**Kitakyushu (Japan)**	**Suzhou (China)**
1	Annul net income of farmers Developed area Less developed area	Yuan/person	≥8,000 ≥6,000	223,790a)	21,389b)
2	Tertiary industry share in GDP	%	≥40	67%c)	47.1% b)
3	Energy consumption per unit of GDP	Tons of standard coal /10k Yuan	≤0.9	0.5e)	0.824 b)
4	Water consumption per unit of industrial added value	m^3/10k Yuan	≤20	n.a.	15.9 b)
	Water efficiency of agricultural irrigation		≥0.55	n.a.	0.636 b)
5	Compliance rate of enterprises should carry out Cleaner production	%	100	n.a.	100 b)

Sources and Notes:
Conversion rate used: 1euro = 8 Yuan, 1 US dollar = 6 Yuan, 1 Yen = 0.07 Yuan
a) Converted from 3,197,000 Yen of Fukuoka farmer income in 2011 (e-Stat Japan Official Database[10])
b) (Li & Qiu, 2015)
c) Calculated from Table 2 of the GDP Brief Results 2010 (Fukuoka Prefecture Website[11])
e) Final energy consumption per unit of GDP in 2010 of Fukuoka Prefecture (RIETI database12)

GDP is a universally recognized indicator for the economic development within given geographic boundaries. In the trial version of the MEP eco-city framework, indicators like “GDP per capita” and “Annual income per capita” were listed, but the final version only keeps the “Annual farmers’ net income” as civil economic measurement. From this change,

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[10] http://www.e-stat.go.jp/SG1/chiiki/CommunityProfileTopDispatchAction.do?code=3
[11] http://www.pref.fukuoka.lg.jp/uploaded/life/19/19167_16466398_misc.pdf
[12] http://www.rieti.go.jp/users/kainou-kazunari/energy/

we can observe a shift from the heavy pursuit of economic prosperity to the genuine concern of a rather economically weak group – the farmers. Despite China's being the 2nd largest economy worldwide, big gaps are still seen between Chinese baseline of farmers' net annual income (8,000 Yuan for the developed areas) to those of Kitakyushu (223,790 Yuan) and Suzhou (223,790 Yuan). It can be inferred that some of China's most developed cities are catching up those of developed regions.

If we take a look at one of the causes for unsustainable development, the blind pursuit of economic development such as GDP growth is definitely on the list. Thus, having attainable goals for economic development of Chinese eco-cities should be implemented on a wider scale. At the same time, the differences of GDP per capita value also indicates that China's economic development baseline is still out-matched by developed countries like Japan, despite of its overall gross performance.

The ratio of the tertiary industries to GDP is rather lower for Chinese eco-cities baseline. The tertiary industry is also known as service industries, which does not rely on raw material or material processing industry. The lower the tertiary industry ratio is, the more share for the first and the secondary industries, which can barely contribute to the overall urban sustainability.

The most relevant two indicators under this category are "energy consumption per unit of GDP" and "unit of industrial added value". The baseline of "0.9 ton/10,000 Yuan" energy consumption and Suzhou's "0.824 ton/10,000 Yuan" is also higher than Kitakyushu's "0.5 ton/10,000 Yuan". Water consumption for industrial added value and water efficiency of agricultural irrigations are not compared due to lack of clear definition and data from Japan.

From these key indicators, it can be easily observed that the Chinese eco-cities still fall behind the developed countries when it comes to per capita energy performances, industrial structural ratio, and resource efficiencies. How to develop the urban economy in a sustainable manner is of vital importance in China, but the current standards have yet to be competitive to the developed world.

3.5.2 Environmental aspect

The environmental protection is one of the core elements for urban sustainable development; as a result, the related indicators can be seen as the most relevant measurement of the “eco” attainment level for eco-cities. I presented all the 11 indicators under this category for comparison (see Table 3-7). What needs to be pointed out is that for air, water, noise and waste categories, each of them needs to comply with the Chinese national standards with dozens of specific indicator measurements. So I have taken the most common ones for separate comparisons, instead of listing all of the items.

Table 3-7 Comparisons of Environmental Indicators for ‘Eco-Cities’

Environmental protection					
NO.	**Indicators**	**Unit**	**Eco-City (Baseline)**	**Japan (Kitakyushu)**	**Suzhou f) China)**
6	Forest coverage	%		38%a)	29.4%
	Mountainous areas		≥70		
	Hilly areas		≥40		
	Plain areas		≥15		
	Percentage of the forestry and grass coverage in alpine area and grasslands		≥85		
7	Proportion of protected areas in total land area	%	≥17	n.a.	37.8%
8	Ambient air quality	Meet the national standards for functional areas[13]		Compare separately	Compare separately
9	Water quality	Reach the standard of functional area and exceeds Class V of water quality		Compare separately	Compare separately
	Coastal water quality				
10	Emission density of key pollutants	kg/10k Yuan （GDP）		n.a.	0.59 0.76
	Chemical oxygen demand		＜4.0		

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[13] Functional area refers to the major functions designated for certain areas, for example, for air quality, there are two classes of functional area, the 2nd class refer to residential, commercial area. For water quality, there are five classes of functional areas.

	(COD)				
	SO2		＜5.0		
		Within national limits			
11	Water quality compliance rate of centralized drinking water source	%	100	n.a.	100
12	Centralized municipal waste water treatment	%	≥85	99.9%[b)]	95.49%
	Industrial water reuse rate		≥80	n.a.	84.74
13	Environmental quality of noise	Reach the standard of functional area		n.a.	Unreached
14	Waste	Urban garbage treatment rate (%)	≥90	100[c)]	100
		Industrial solid waste treatment & utilization rate. (%)	≥90	n.a.	98
15	Urban public green area per capita	m^2/person	≥11	12[d)]	17.45
16	Environmental protection investment share in GDP	%	≥3.5	2.9[e)]	3.1

Sources and Notes:

a) Forest statistics of Kitakyushu City in 2012[14]
b) Year Book of Fukuoka Prefecture, 2010, p.227[15],
c) National law in Japan mandates to have 100% waste treatment and it is considered to have been achieved
d) Kitakyushu Environment White Book, 2010, p.91[16]
e) City budget published at Kitakyushu city official website[17]
f）（Li & Qiu, 2015）

China's "green area" consciousness is more practiced especially under the influence of "garden city" initiatives, which have been undertaken nationwide since the early 1990s,

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[14] http://www.city.kitakyushu.lg.jp/san-kei/file_0461.html
[15] http://www.pref.fukuoka.lg.jp/uploaded/life/18/18320_16266500_misc.pdf
[16] https://www.city.kitakyushu.lg.jp/files/000041528.pdf
[17] http://www.city.kitakyushu.lg.jp/files/000121405.pdf

which is indicated by the “Forest coverage rate” of 40 % (Hilly area) compared to Kitakyushu’s 38.3% and 15% (Plain area) to Suzhou’s 29.4%. 11m^2/person in “Urban public green area per capita” is very close to Kitakyushu’s 12 m^2/person, which is rather satisfactory given the population in most Chinese cities.

Categories of “Air” “Water” and “Waste” are the most important aspects to any city, which is universally acknowledged and accredited as the major components to urban environment. By comparing these indicators, we can obtain the most direct impression of a city’s ecological level. Air pollution in many Chinese cities is already in crucial condition for urban environmental development. Beijing for example, among many other mega-cities has been tortured for its air related problems, causing severe public health concerns and indirect economic damages, besides the environmental sides.

It is worth noting that the “eco-cities” standards set by MEP do not bring out new sets of indicators nor thresholds, all their standards comply with the “Ambient air quality standards” (GB3095-1996). While this set of standards was renewed in 2012 (GB3095-2012), so the figures that included for comparison is taken from the 2012 standards instead of the 1996 one. Moreover, the eco-city standards trial version requires the number of days in year to meet the Class 2 standards (of “Ambient air quality standards”), for north of China – no less than 280 day, south of China – no less than 330 days. This might lead to the suspicion of “loosened requirements” for the northern cities than southern ones due to industrial development needs and population growth patterns. What is worse, it allows time window (85 out of 365 days, 35 out of 365 days) for the eco-cities not to meet the air quality standards, causing possible ill implementation of air pollution on a macro-level. However, during the revision version, the number of days is removed, eliminating the loop holes mentioned, indicating that the government has been gradually improving their requirements for air quality.

To compare the air quality for the three cases, four major indicators for measuring air quality are chosen among several dozens of measurements, namely, the daily mean for annual nitrogen dioxide, ozone, particle matters (such as PM10, PM2.5), and sulphur dioxide. The results reveal that the thresholds are several times more than that of Kitakyushu and Hamburg (refer to Table 3-8). This suggests a huge gap between the Chinese eco-cities and developed nations for air quality.

Table 3-8 Selected indicators for air quality comparisons

Air quality	**Selected indicators**	**Eco-city (Baseline)**	**Kitakyushu[a)] (Japan)**	**Suzhou[b)] (China)**
Standards for 2nd Class functional areas (residential and commercial area)	Annual mean for SO2 (μg/m^3)	60	11 (0.004ppm)	23
	Annual mean for NO2 (μg/m^3)	40	39 (0.019ppm)	53
	24-hour average for CO (mg/m^3)	4	0.5 0.4ppm (Annual)	0.92
	1-hour average for O3 (μg/m^3)	200	81 0.038ppm (Ox)	95
	Annual mean for PM 10 (μg/m^3)	70	16.8 (0.026ppm)	86
	Annual mean for PM2.5 (μg/m^3)	35	18.2	66

Sources and Notes:

a) Conversions of ppm to μg/m3 formulate (mg/m3=M/22.4*ppm18) are employed to unify the units
b) (Li & Qiu, 2015)
c) Observed values in 2011 from Fukuoka Prefecture Web Site19

Water is also an essential resource for human survival and development, and a huge challenge in China due to its severe shortage and pollution. It is also regarded as one of the key factors that affect the ecological development of cities, which is reflected by the quantity of indicators. From Table 3-9, we can observe that the pH range is rather similar and natural in terms of acidity and alkalinity. COD value is 5 times higher than Kitakyushu, suggesting

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[18] The complete formula is mg/m3=(M/22.4)*ppm*[273/(273+T)]*(Ba/10132), for the sake of easy calculation we assume T=0, Ba=10132.

[19] http://www.pref.fukuoka.lg.jp/c01/h23-taiki-data.html

more pollution contents in Chinese water bodies than in Japan. The other thresholds of BOD5, Nitrogen (NH3-N) and Prosperous (P) are all higher than in Kitakyushu, indicating the overall quality of water is out-performed by Japan. A more subjective comparison is that the tap water in Japan is directly drinkable, while few people in China would drink water straight from water tap. Most people in China, if not all, at least boil tap water before drinking, just to avoid unnecessary health risks.

Table 3-9 Selected indicators for water quality comparisons

Water quality	**Selected Indicators**	**Eco-city (Baseline)**	**Kitakyushu[a)] (Japan)**	**Suzhou [b)] (China)**
Standards for 3rd Class functional areas (residential and commercial area)	pH	6-9	7.1	n.a.
	COD (mg/L)	≤20	4.1	4.60
	BOD_5 (mg/L)	≤4	1.3	2.44
	NH_3-N (mg/L)	≤1	n.a.	2.93
	P (mg/L)	≤0.2	0.014	0.44
	Cadmium (µg/l)	≤5	<1	n.a.
	Lead (µg/l)	≤50	<5	n.a.
	Mercury (µg/l)	≤0.1	Not Detected	n.a.

Sources and Notes:

a) Observed values in 2011 in a point near the center of Kitakyushu City, from Fukuoka Prefecture Web Site[20]
b) (Li & Qiu, 2015)

China's "urban waste water treatment percentage" target is 85%, which is considerably less than of Kitakyushu. Moreover, law and regulations pertaining to wastewater treatments

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[20] http://www.pref.fukuoka.lg.jp/c01/h23-taiki-data.html

mandates no discharge of untreated wastewater in both countries, which would offer a good reference for the future related legal frameworks in China.

Waste is a serious problem in many developing countries and China is no exception. On the other hand, “waste” has become a booming industry to produce “added-value” products rather than “value-consuming” waste to be rid of. There is only one category with two indicators from MEP’s standards – “Urban Garbage Harmless Treatment Rate” (≥90%) and “Industrial Solid Waste Treatment & Utilization Rate” (≥90%). Both of the laws in Germany and Japan mandate that all the urban wastes must be treated before disposal in landfills. Industrial wastes are not compared due to differences in definitions and calculation method.

There are several major approaches for urban garbage or waste treatment, for example, recycling, landfilling, incineration, MBT (mechanical and biological treatment) etc. 100% treatment by landfilling is far from 100% treatment by incineration and MBT in terms of environmental soundness. In many developed countries, landfilling is getting less and less popular given its eco-and-environmental threats (landfill gas emission and leakage to soil and underground water body among others). In this sense, a better approach would be for MEP to come up with specific indicators for waste recycling, treatment mechanisms and so forth. The gross amount of Chinese waste generation is astonishing, but if properly dealt with, this also embeds huge potential for eco-performance improvements and business opportunities.

3.5.3 Social aspect

As one of the three pillars for sustainable development, “social aspect” is the most commonly included but yet least commonly standardized and consensus-based, due to the vast diversity in geographical, cultural, political, institutional features worldwide. Even for the same category, due to the methodology adopted, the results can be quite different sometimes. It should be noted that the ‘central heating rate’ indicator applies only to the many cities in the northern part of China, thus not applicable in either Japan or Germany.

Table 3-10 Comparisons of social indicators for ‘eco-cities’

Social progress				
NO.	**Indicators**	**Eco-city (Baseline)**	**Kitakyushu (Japan)**	**Suzhou** [b] **(China)**
17	Urbanization rate	≥55%	89.9% [a]	79.13%
18	Centralized heating supply rate in heating region [c]	≥65%	n.a.	n.a.
19	Public satisfaction rate on the environment	≥90%	61.6%[d]	93.83%

Sources and Notes:

a) Calculated based on Population Census 2010, at e-stat database[21]
b) (Li & Qiu, 2015)
c) This item is unique for only Chinese northern cities, not applicable to neither Japan nor Germany
d) According to a survey conducted by the Green Master Plan for Kitakyushu

According to the World Population Prospect (United Nations, 2012), China’s urban population exceeded 50% in 2011[22]. Over half of the world’s population is currently living in urban areas, and more than 2/3 of the population in the developed countries lives in urban area. However, for many developing countries, pursing urbanization is still a major driving force for social development. The effort of maintaining a stable urbanization pace in China can be detected by this 55% urbanization target, which is much lower compared to 79.13 % in Suzhou city and Kitakyushu’s 89.9 % urbanization rate in Japan. This obvious gap in percentage indicates that China, despite its highly developed cities, has still a long way to catch up with the urbanization levels of the developed world. Just by setting up an “urbanization rate” target, however, does not guarantee its development in a sustainable

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[21] https://www.e-stat.go.jp/SG1/estat/eStatTopPortal.do
[22] http://esa.un.org/unup/unup/p2k0data.asp

manner. It is the “means” – the path we adapt for realizing the development goal, rather than the “end” – the goal itself that really contribute to sustainability.

Now, one of the most ambiguous indicators is found during this study - “Public satisfaction rate for the environment”. China’s MEP has a high target of more than 90%, and 93.83% in Suzhou city, which completely outperforms the 61.6 % in Kitakyushu. The methodology provided by MEP states to determine this value is through conducting “on-site questionnaire survey”, but so far we could not find if they have specified the details about the sampling method and questions to include. Undeniably, the result can be as high as 90% or more, based on the questions for such subjective opinions. More investigations are needed to see why the Chinese standard has to be set this high.

Having a high threshold should contribute to overall achievement of making eco-cities truly ecological, but sometimes this unrealistic goal could play no part or even have a negative effect in realizing the original intentions.

3.6 Chapter Conclusion and Discussion

Multi-diversity is seen in terms of both contents and quantity for eco-city frameworks, guidelines and indicator systems from within China as well as the international communities. The overall 8 aspects of energy, water, air, waste, transportation, economy land use, and social aspect can be universally observed, but the specific indicators vary greatly according to a series of factors like geographical, political, institutional and methodological pursuits. It is very unlike to have a “panacea” (a cure for all) to develop a single universal framework addressing all the needs of various regions and countries, but case-specific approach.

Even within China, almost a dozen indicator systems are proposed by a number of entities from different social backgrounds. Two sets that are currently available and legally binding is from MHURD and MEP, and joint ventures tend to have their own standards and indicator systems. The quantity of indicators vary from one system to another, and each of them addressed their own development agenda, which focus on rather limited aspects for achieving urban sustainability.

The current MEP’s eco-cities indicators in China, compared to two ecological cities in real life case of Suzhou city and Kitakyushu city in Japan have indicated the following conclusions:

- Averaged economic figures like GDP/Income per capita etc. greatly outperformed by Japan
- Efficiency threshold like Water and Energy Consumption is still lower than in Japan.
- Green area/space related indicator thresholds are nearly the same as in the two countries
- Environmental related standards for “water” and “air” are much far behind than those of in Japan, indicating Chinese eco-cites environmental performances are way worse than in the developed countries. Too little content is given to the “waste” sector, which could have helped more to urban sustainability if proper mechanism is included
- Social aspect related indicators like “urbanization rate” and “Centralized heating rate” are reasonable in terms of China’s current development stage, which should have taken a steady not speedy approach.
- The subjective indicator like “Public satisfaction rate for the environment” is very high, indicating possibly indicating an ambiguous methodology for conducting such samplings or a “national confidence” of the people in China for poll.

Compared to the leading countries in eco-city developments, China’s eco-cities seem less “eco”, and many aspects could be improved and revised to better suit the sustainable urban developments. It is less convincing to reach a definite superior or inferior conclusion for the Chinese eco-cities compared to those of the developed countries due to their geo-cultural differences and local context.

What can be observed, however, are the occasional lowered standards, thresholds, and unrealistically high targets without explicit method of assessment or evaluation for China’s eco-city development. Compared to other international eco-cities, Chinese ones still have a long way to go, and much room for improvement in terms of the framework, indicator systems. And urban sustainability should not be an end goal but a process that makes the cities more ecological, more sustainable and more livable.

4 LOW-CARBON CITY DEVELOPMENT IN CHINA: LESSONS AND REFERENCES FROM OTHER COUNTIRES

Succeeding the global urban trend of eco-city development, the low-carbon city became the next “norm” for a new trend of urban development towards sustainability. “Low-carbon” has become the very core element of this wave. To pursue the urbanization in a sustainable and low-carbon manner, the Chinese government has strenuously enacted an array of corresponding urban policies. This chapter[23] reviews these policies with particular focus on the “low-carbon” cities in China, and finds that China’s major objective towards low-carbonization is to reduce CO2 emissions with proper adaptation plans. A strong focus is placed on governmental interventions that result in positive civil effects regarding carbon reduction. Additionally, two case studies from other countries are introduced to offer lessons and references for China’s low-carbon city development.

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[23] Bases on this chapter, a paper has been published as Zou, X., & Li, Y. (2015). “Developing Tailor-Made Urban Environmental Policies for China’s Low Carbon Cities - Implications from Japan and Germany”. In Feng, S., Huang, W., Wang, J., Wang, M. & Zha, J. (Eds.), *Low-carbon City and New-type Urbanization.* (pp. 273-284): Springer Berlin Heidelberg. .

4.1 Chapter Introduction

Under the fast economic development and rapid urbanization process, China is currently one of the world's largest energy consuming and greenhouse gas (GHG) (commonly measured by CO2 equivalence) emitting nation in the world (Jiang & Tovey, 2009). Since the 1990s, a range of policy initiatives has been taken by the Chinese government to reduce the GHG emissions on both national and local levels.

The Chinese government has put relentless efforts into achieving the urbanization and economic development ventures while seeking balance with nature and development in a sustainable manner. These efforts begun with the very first appearance of China's "eco-city" project in Yichuan city, Jiangxi province in 1986, and continues to the recently released new model strategy of "National New-type Urbanisation Plan (2014-2020)", which aims to redirect the nation's urbanization towards a human-centred and environmentally friendly path. The Chinese government has put relentless efforts into achieving the urbanization and economic development ventures while seeking balance with nature and development in a sustainable manner (Zou & Li, 2015).

A variety of frameworks, indicator systems, initiatives and programs of "sustainable cities" can been seen in China. Several major national frameworks or programs have been proposed by the government, namely, "the Eco-Garden City" program by the Ministry of Housing, Urban and Rural Development (MHURD), the "Eco-County, Eco-City and Eco-Province Indices" by the Ministry of Environment Protection (MEP), and "the Low-Carbon City" program by the National Development and Reform Commission (NDRC). These programs have attracted over 90% of Chinese cities (of municipality level and above) to participate[24].

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[24] Chinese cities are defined by administrative boundaries and contain at least 100,000 non-agricultural residents. Three administrative types of cities (provincial- level municipalities, prefecture-level cities and county-level cities)

However, unlike the MEP or MHURD which offers specific indicator systems, NDRC’s low-carbon city program is still in the trial phase, with eight pilot cities and five pilot provinces, requesting the piloting entities to come up with their own set of indicators. From the trajectories of China’s national urban policies, it can be observed that the focus has shifted from dealing with pollution and setting up greeneries in the urban areas led by eco-garden cities, to the pursuit of integrating urban planning and managing with ecosystem merits implied by eco-cities, and to the decoupling from fossil fuel uses and the pursuit of energy efficiencies, renewable technologies for reducing carbon emissions (Zou & Li, 2015).

As the “new norm”, carbon reduction has been brought up to atop national policy in China, as in most parts of the world. In 2009, the State Council announced the target of reducing its GDP carbon intensity by 40-45% by 2020 compared to the 2005 level (State Council of the People's Republic of China, 2009); And later in the 12th Five Year Plan, a binding target of 17% CO2 reduction per unit GDP from 2011 to 2015 was set as a national goal (National People's Congress, 2011), which greatly incentivize the low-carbon cities development in China.

There is a thriving amount of literature in examining Chinese low-carbon cities in terms of concepts (Yang & Li, 2013), developments (Kahri et al., 2011; Li, Zheng et al., 2012) and promotions of individual low-carbon cities (Zhou, 2012; Li, Zheng et al., 2012; Su et al., 2012). Some works focused on China’s macro transition towards low-carbon economy development (Chen, 2015; Qin & Han, 2013). Some scholars studied specific low-carbon practices or implementation strategies in energy and power sectors (Li, Z. et al., 2012; Xi et al., 2011), technological innovations (Zhang et al., 2012), urban policies (Feng & Zhang, 2012), infrastructure and construction sectors (Bi et al., 2011, Qi & Wu, 2013) and specific city case studies (Zhang, 2010, Lehmann, 2013, Kahri et al., 2011). However, there is less work conducted to evaluate the policy-driven low-carbon cities implemented in China with international references (Sun, 2014).

This chapter combs through the major national urban policies to summarize the characteristics in a conceptual sense and focus on the current status quo of Chinese low-carbon cities, to offer a holistic view of China’s urban policy transformation. Under the current tide of low-carbon urbanization, what could be the lessons learned via the two case studies of Germany and Japan for the on-going pilot low-carbon cities in China? The German case of Rhein-Hunsrück District demonstrated how rather flexible energy policies have helped to transform that region from an energy importer to an exporter. And the Japanese eco-town project of Kitakyushu indicated that technological innovations have significantly contributed to the city's low-carbon target. Both of them may offer suitable guides to China's low-carbon city developments (Zou & Li, 2015).

4.2 Development of China's Major National Urban Policies

4.2.1 International background

Modern urban policies can be dated back to the post industrial revolution UK, when England's Ebenezer Howard proposed the concept of "Garden City" in the late 19th century, as a means to mitigate the concentrated and polluted urban working, living space and environment with smaller resident settlements of 30,000 to 50,000 people surrounded by green spaces like parks and trees. This conceptual framework has laid the foundation for the future urban policies across the world. After Second World War, specially between the 1960s and 1970s, many industrialized countries like the United Kingdom, Germany, France and Japan restored and prospered significantly due to the rapid economic growth coupled with fast urbanization. At the same time, they began to suffer from the "urban illnesses" of housing shortages, deterioration of living conditions and national environments, growing pollution related problems like traffic and dispreading of green space etc. It was during this period that the first wave of sustainable urban policies like the "ecopolis" in Germany and "amenity town" in Japan were put into place, which became the impetus for developing "eco-cities" as we know today (Imura, 2010).

4.2.2 China's low-carbon urban policy developments

On the founding of the new nation in 1949, China was still concerned with the previous wounds of imperial and civil wars. With the severe "domestic disturbances", there was virtually no viable environmental legislation until the 1972 United Nations Conference on the Human Environment in Stockholm, when the bell of environmental awareness was rung. And only after Deng Xiaoping's "Reform and Opening Up" policy sprang across China in 1978 and onward, accompanied by fast economic growth and urbanization, came the nurturing bed for the subsequent national urban environmental policies (Bao, 2012).

In the year 1986, Yichuan City (Jiangxi Province) brought up the proposal of developing the first "eco-city" like project in China, which was an indication of the local government's effort to tackle the local environmental and ecological challenges cased during the rapid urbanization. In the early 1990s, the former Chinese Ministry of Construction (MoC) enacted national a framework of "Garden City", focusing on the landscape and green space urban developments. This was the first national scale attempt to right the urban development into a more sustainable trajectory. In 2004, MoC's successor, the Ministry of Housing Rural and Urban Development upgraded this framework into "Eco-Garden City", addressing with more pressing and comprehensive indicators for the related urban developments (MHURD, 2004). In the same year, the Ministry of Environment Protection came up with a national framework of Eco-cities (containing three levels, county, city and province), with more standardized concepts and indicators for urban development (MEP, 2004). Then in 2008, the National Development and Reform Commission (NDRC, 2011) initiated the nation wide call for "Low Carbon City" developments, in an attempt to realize the CO2 emission reduction target set in the 11th Five Year Plan (as shown in Figure 4-1). And according to a survey by Chinese Society for Urban Studies (2012), 280 cities (of municipality level and above) have developed goals or plans for developing low-carbon cities or eco-cities, accounting for over 97% of the Chinese cities (of municipality level and above) (Zou & Li, 2015).

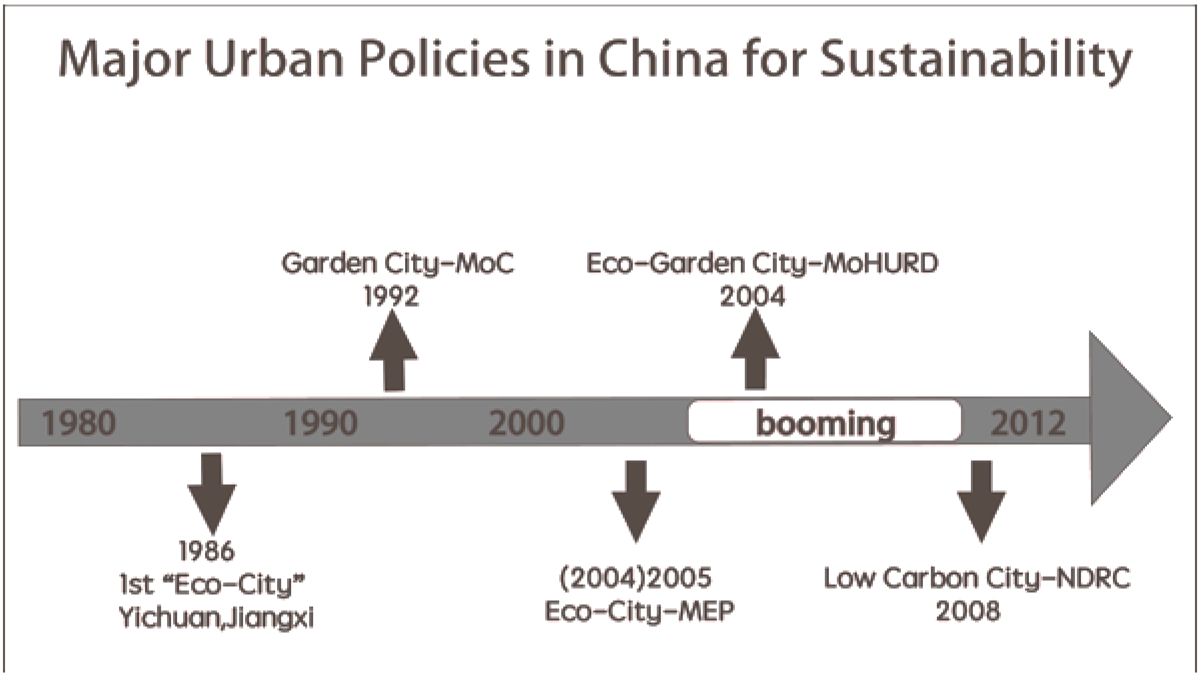

Figure 4-1 China's Major National Sustainable Urban Policies

Source: Gov. Sites; (Chinese Soceity for Urban Studies, 2012; Qiu, 2010)

The abundance of such projects doesn't necessarily guarantee the successful realization of urban sustainability or low-carbonization for cities. But it indeed manifests the significant effort that the Chinese government has put into transforming the urban development strategies in a more sustainable manner. However, there has not yet been any well-established eco-city or low-carbon city in China that could offer up-scaling practices for other cities. Despite the existence of renowned cases such as Sino-Singapore Tianjin Eco-City, these Sino-Foreign projects are far from completion and nationwide dissemination (Zou & Li, 2015).

4.3 China's Low-Carbon Era

China took the lead amongst the developing countries to formulate and implement National Plan for Climate Changes (Chen, 2007). NDRC issued the National Climate Change Program in accordance to UNFCCC provisions for addressing climate change. In 2009, the State Council announced a carbon intensity reduction target of 40-45% by 2020 compared to the 2005 level (State Council of the People's Republic of China, 2009). China took a further step of incorporating this target into the 12th Five Years Plan (FYP), with a legally binding target of 17% of CO2 reduction per GDP unit from 2011 to 2015 (National People's Congress, 2011). Hence, low carbon development has become the new norm in China's urban and economic developments. A series of policies, regulations and frameworks have been put in efforts to support the related low carbon projects, initiatives and programs nationwide.

Since 2005, China's Ministry of Housing and Urban-Rural Development has formulated several policy measures to promote public transportation and low-carbon constructions. In 2010, the NDRC officially put forward the initiative of experimental demonstration projects of low-carbon urban development in "five provinces and eight municipalities", which received active and extensive support from local governments. Later that year, State Council issued the Notice on Issuance of National Plan of Main Functional Areas, proposing "the development of low-carbon cities and reducing the intensity of GHG. In 2011, State Council issued the Opinions on Implementation of Division and Specialization of Key Departments in the Government Work Report, proposing to "advocate the experimental works of low-carbon cities"(Sun, 2014). The Ministry of Finance (MoF) and MHURD jointly issued the Notice on Implementation of Low-carbon Demonstration Town Pilot Program, promoting sustainable low carbon developments in small cities and towns (MoF, 2011).

By 2012, approximately 97% of China's prefectural level cities had announced goals for developing eco-city or low-carbon city based on the survey conducted by Chinese Society for Urban Studies (2012) as shown in Figure 4-2.

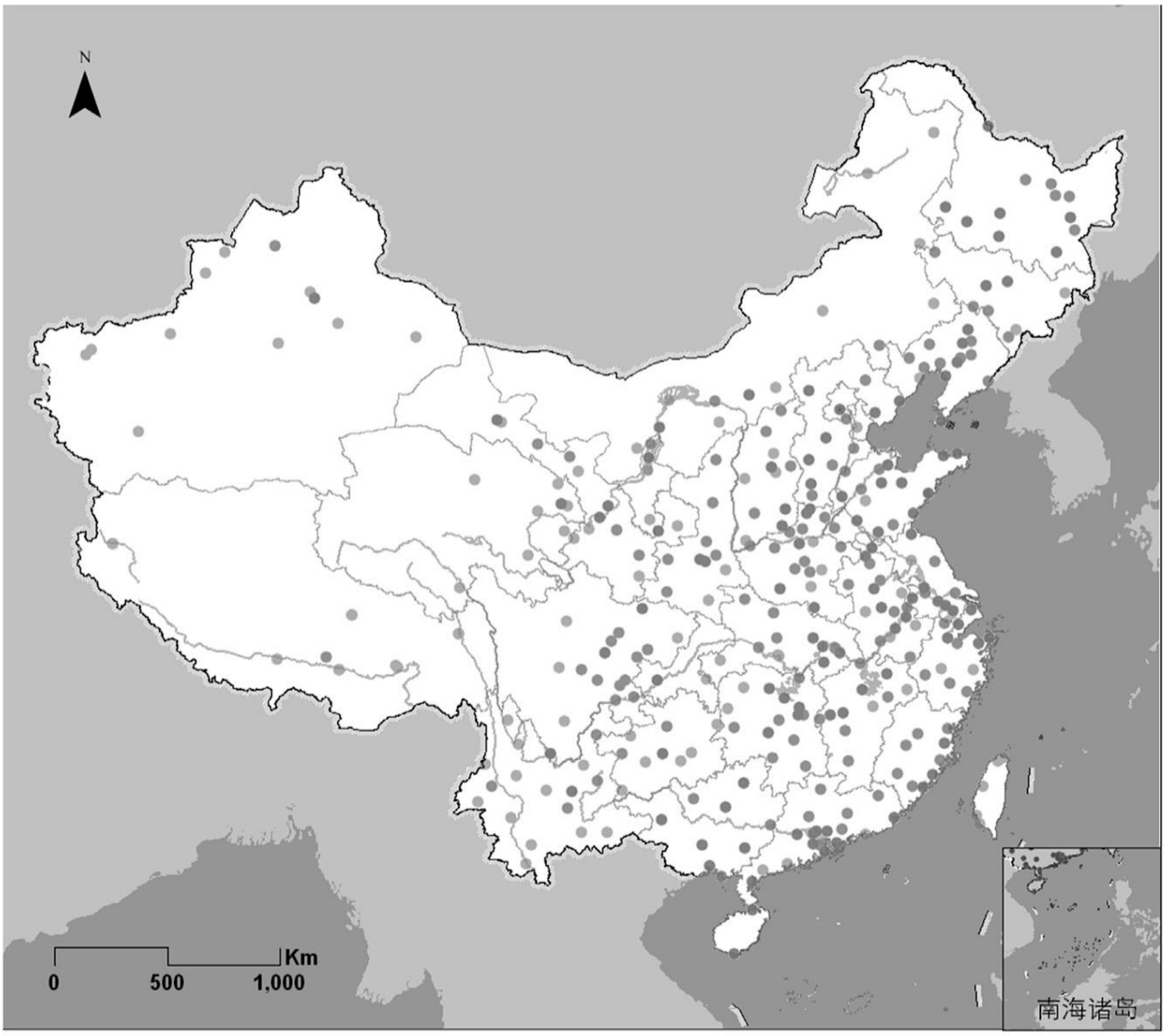

Figure 4-2 Chinese cities expressing the goals to pursue or adopt eco-city or low-carbon city development goals or plans.

*Source: (*Chinese Society for Urban Studies, 2012*)*

After reviewing these major national urban frameworks and policies, a number of distinguishable features as well as shortcomings are observed (Zou & Li, 2015):

- China's urban policies have mirrored the world's sustainable development trends especially since the 1980s onward, which normally reflected and addressed the major problems that occurred during that particular time under the global context. This suggests China's quick adaptation and responses to both domestic problems and international responsibilities.

- China’s national urban plans are well accepted by the local governments particularly in terms of the low-carbon eco-city projects and initiatives. However, despite the large quantity and zealous participations, the successful cases that would offer larger scale implementation are still insufficient. This is particularly due to China’s vast geographic and geopolitical features, demographic characteristics as well as the uneven developments amongst cities, provinces and regions. Developing local or regional appropriate adaptations of urban development models seem a rather reasonable principle.
- A shift from implementing top-town policy to developing bottom-up policy was gradually put into place. This is suggested by the different policy approach from Garden/Eco-Garden City to Low-carbon City, when the former calls for the implantation of framework and indicator systems proposed by the national government, and the late one encourages local government to develop their town master plans based on regional features under the central guideline. This is indeed a big advancement in urban environmental policy development for China.
- However, due to the lack of explicit definitions or clear distinctions of related concepts, such as “eco-cities”, “low-carbon cities” or “low-carbon eco-cities”, severe duplicates and overlaps are seen in the implementation of local urban actions. Many cities have participated in multiple pilot or trial programs, which causes complexity in implementations and more pressures on the local administrations and less efficiencies in program completions.

When it comes to the current status of low-carbon pilot cities in China, after reviewing their development master plans, Khanna et al. (2014) found that many of the low carbon cities have too broad scopes, and might not sufficiently tackle the essence of carbon mitigation (e.g., energy efficiency). Another key finding is that given the infancy status of low-carbon development, local city planners are still lacking in knowledge related to low-carbon policies and practices. This suggests that China's low carbon cities still have a long way to go, besides the eager pursuit of developing domestic low-carbon city, actively referring to the international experiences, expertise of their best practices would produce valuable inputs to China's current endeavors (Zou & Li, 2015).

4.4 Lessons and Implications from Other Countries

From a global perspective, the low-carbon urban strategies vary in different regions, and defined by particular local context and country geo-political settings. In Asia, countries like Japan and Singapore pay more attention carrying out the top-down management style to implement the national urban policies into the local levels (Chinese Society for Urban Studies, 2012, p.12). China, despite its ambitious targets of GHG reduction and enthusiasm for developing low-carbon eco-cities, still need to refer to the best available practices for inspirations and know-hows. In the following part of this paper, two case studies are enlisted from Japan and Germany, the two leading countries in low-carbon sustainable urban developments worldwide, to seek nutrients that would benefit China's local practices.

4.4.1 Case Study of Japan: Kitakyushu Eco-Town Project

Japan is a leading country in terms of establishing low-carbon development strategies coupled with its technological advantages and financial powers. In 2008, the Japanese government announced an ambitious goal of "Low-carbon Society" (LCS) by reducing 60% to 80% of its CO2 emissions (compared to 1990's level) by 2050. Later in 2009, then Prime Minister Hatoyama complimented this "ambitious pursuit" with a mid-term plan of reducing 25% of CO2 emission by 2020 (compared to 1990's level).

Efforts of different levels of government in Japan have been made towards realizing their commitment of low-carbon society. In this section, the City of Kitakyushu is enlisted as an example for an in-depth understanding of its transformation from the once notoriously polluted industry center to today's world-renowned low-carbon green city in Japan.

Kitakyushu: From Pollution to Recovery[25]

Before the turn of the 20th century, the City of Kitakyushu was a sleepy fishing village of about 1200 people. It is close to domestic coalmines in Kyushu region, and also nearer to the neighbouring China than the rest of Japan, where iron ore was in abundance and convenient for transformation. These advantages led to the establishment of the National Yawata Steel Works[26], one of the earliest large-scale steel factories in Japan. Due to these factors, this area underwent a period of rapid, unchecked industrial production, and the area became prosperous.

Figure 4-3 National Yawata Steel Works at Present.

Source: Taken by the author in May, 2014.

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[25] Information from Kitakyushu City Government Page http://www.city.kitakyushu.lg.jp/english/

[26] The site was accepted at the 39th UNESCO World Heritage Session.

However, this was an era before even the most basic end-of-pipe measures to contain emissions, and it was quite apparent. The multi-colored smoke that continually emitted into the atmosphere was referred to by the locals as the "seven colour sky," or the rainbow sky. This was something to be proud of, it was a symbol of the economic prosperity that had been had in the region. The Dokai Bay, on the other hand, came to be known as the Sea of Death. According to a 1966 study, it had a dissolved oxygen level of 0, and even bacteria could not survive in the water.

Figure 4-4 "Seven Color Smoke" and "Dokai Bay" in the Past.

Source: Pictures taken by the author in May, 2014, at local museum.

The Women's Associations of Kitakyushu

The first people to suspect something was amiss were the local women. In the 1950s and 60s, it was the housewives who were mainly responsible for upkeep of the houses and of the health of the family. They were the ones in an endless futile fight against soot buildup in their houses, and they were the ones who noticed that children especially always seemed to be having respiratory problems, skin issues, eye irritations, and other ailments. It was the women who first began to wonder if there might be some connection between the "rainbow sky" and this constant sickness.

As part of the postwar democratisation efforts taking place in Japan, social education was being carried out at community centres. At one of these centres, the Tobata Women's Association decided something had to be done. However, because the factories at fault for the pollution were also the main source of income for these women and their families, it created an awkward predicament. Therefore, rather than directly antagonising the companies, the women instead began collecting evidence. They worked with a professor from Yamaguchi University to devise experiments to prove the correlation between factories and soot buildup, the results of which they then presented to the city council. In 1965, the Tobata Women's Association produced and directed a documentary film called Aozora ga Hoshii, or "We Want A Blue Sky." The film was released nationally and caused a scandal. The women's associations had successfully presented pollution as a public health concern. Finally, under this pressure, the city government passed a Pollution Prevention Ordinance, leading to a rapid tightening of pollution emission standards that surpassed those of the federal government.

Kitakyushu's Transformation towards Sustainability and Eco-Town Project

The present day City of Kitakyushu is located in the north of Kyushu area of Japan, with a territory of 485 km^2. From 1950s to 1970s, this heavy industry city of iron manufacturing was severely polluted, especially in the air and water. The Dokai Bay of the city was so contaminated that it gained the nickname of "Sea of Death", and the public health suffered profoundly due to the heavy pollution (see Figure 4-5).

Through decades of continuous and strenuous efforts of environmental protection and sustainable developments, the city has returned to blue sky and clear water, and has been awarded frequently with its efforts in sustainable urban transformation internationally, and has been awarded or selected as a model city by the national government and international organizations including the UN and OECD (OCED, 2013).

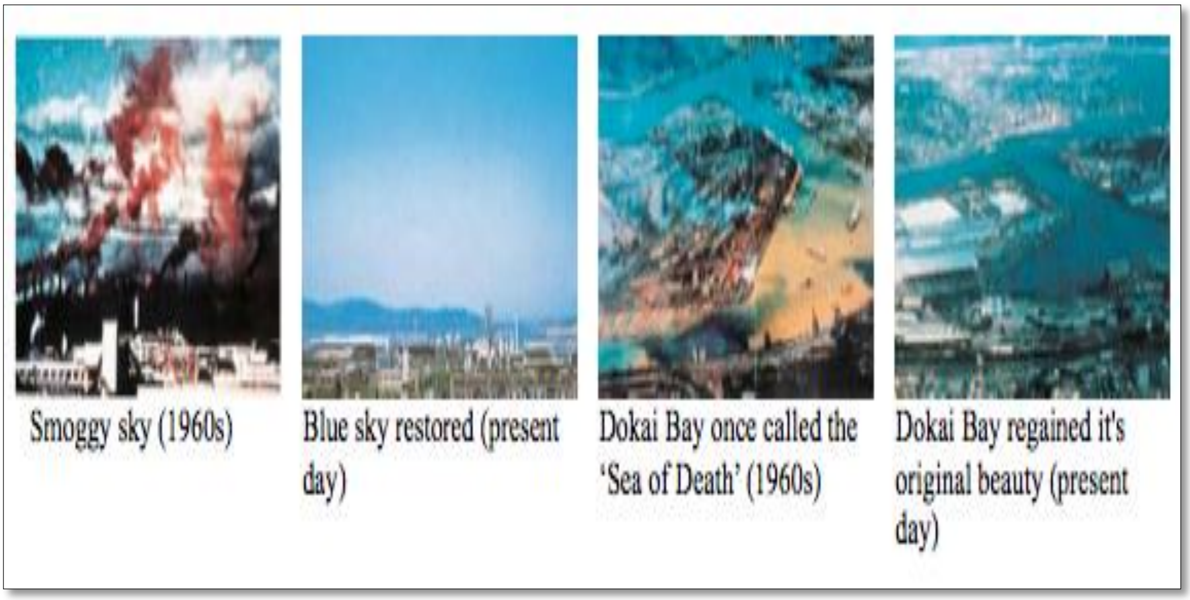
Smoggy sky (1960s)
Blue sky restored (present day)
Dokai Bay once called the 'Sea of Death' (1960s)
Dokai Bay regained it's original beauty (present day)

Figure 4-5 Kitakyushu in its Past and Presence.
Source: (Institute for Global Environmental Strategies, 2005)

The Eco-Town Project in Kitakyushu city encompassing the entire eastern section of the Hibiki Landfill Area was firstly approved by Japan's then Ministry of Industrial Trade and Industry (MITI) in 1997, which later became the Ministry of Economy, Trade and Industry (METI) in 2001. METI greatly promoted this project and offered subsidies for the constructions of infrastructures as well as marketing. There are two stages of the project with over all aim to promote zero emissions though reutilizing the wastes of the local industries, contributing to the 3R (Reduce, Reuse and Recycle), society development of Japan with the first stage (1997-2002) focusing on the "Recycle" and the second stage (2002-2010) focusing on "Reuse". The overall strategy is to link together academic research, demonstrative and applied research, and business sector of the local industries, to have jointly efforts of all these components working together (Dhakal, 2002).

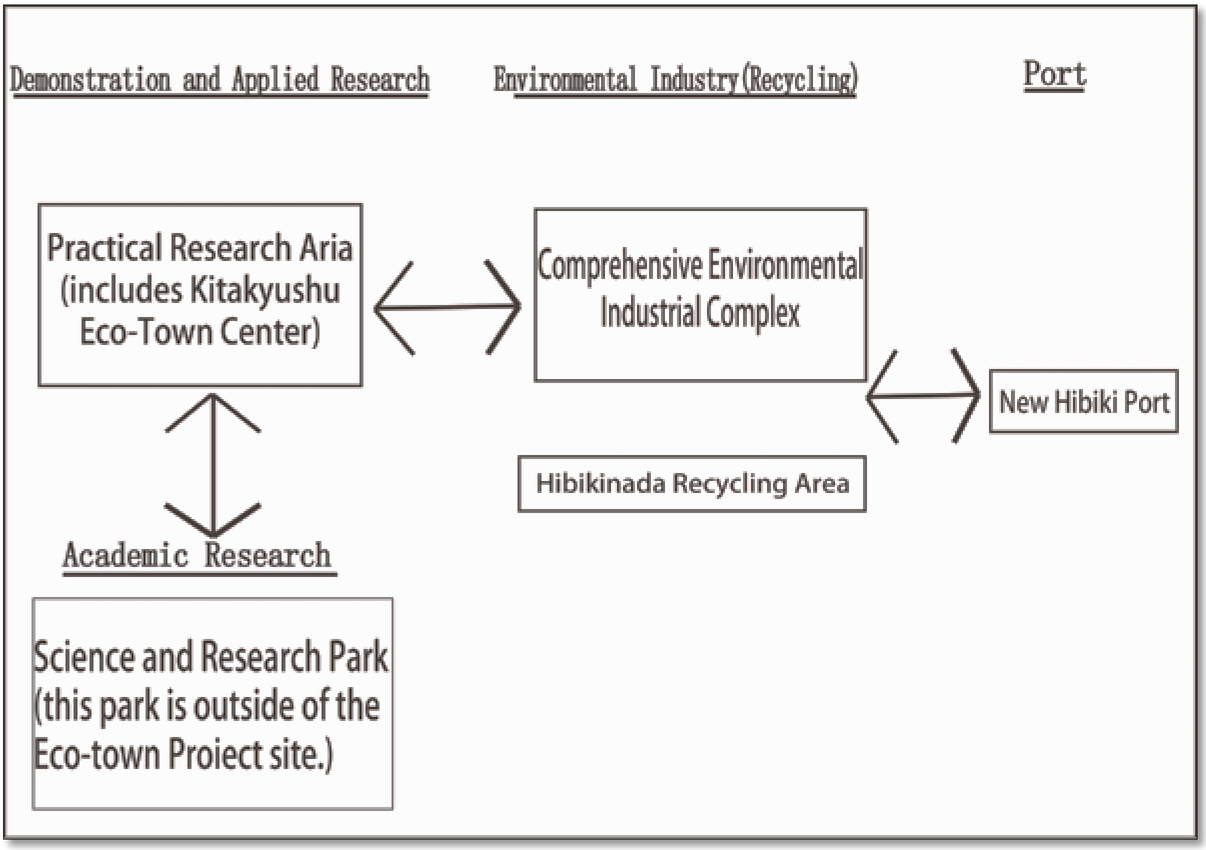

Figure 4-6 The Components of Kitakyushu's Eco-Town Project

The successful outcomes of this eco-town project of Kitakyushu city have made an international brand for Japan's local practices of eco-city initiatives. Moreover, in terms of financial values, a total 50, 200 million Japanese yen was invested, of which 7% came from the private sector; over 1000 jobs were created. An accumulated 109,300 million yen was invested from 1998 to 2003.

Lessons Learned

Through the promotion and financial support of the government for the eco-town project, Kitakyushu city has transformed itself from a heavily polluted industrialized city into an environmental industry city that featured in R&D in environment technology, and demonstration center for resource recycling of the local industries with tangible economic gains. Through proper design, financing from both public and private sectors, integrated with the academic research and sciences, the Kitakyushu city has become a good indication of how to re-develop an industrial city in a more sustainable, low-carbon manner (Zou & Li, 2015).

4.4.2 Case Study of Germany: Rhein-Hunsrück District – Renewable Energy

The District of Rhein – Hunsrück has a territory of 963 km^2 in the State of Rhineland-Palatinate in the southwest of Germany. There are approximately 103,000 residents in the district in 134 settlements, and 75% of them have less than 500 inhabitants. This district has the goal of converting the 290 million euros that spent on importing energy from outside of the region into regional community added value and jobs through improving energy efficiency and introducing renewable energy and switching its energy system into high-efficient, local renewable sources powered system by 2020[27]. In 2009, the total electricity demand in the district was 473 million kWh and in 2012, the share of electricity from renewable sources had reached 149%, and is expected to reach 286% by 2015 (Fleck, 2013).

The transformation process of Rhein – Hunsrück District started in 1999, when the local authority started to control the energy usage in the district owned properties. In 2003, the district started to optimize the local building and improve energy efficiencies. In 2006, the district decided to develop their own comprehensive Energy Concept for the district. They commissioned a local research institute to integrate climate protection management schemes based on the already established concepts and aim to encourage more use of renewable energy and public participation, to achieve “Zero-Emission” by 2020 (see Figure 4-7).

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[27] http://www.go100percent.org/cms/index.php?id=77&tx_ttnews%5Btt_news%5D=258&cHash=81261a7fdf5436a56620c595d7f531c9

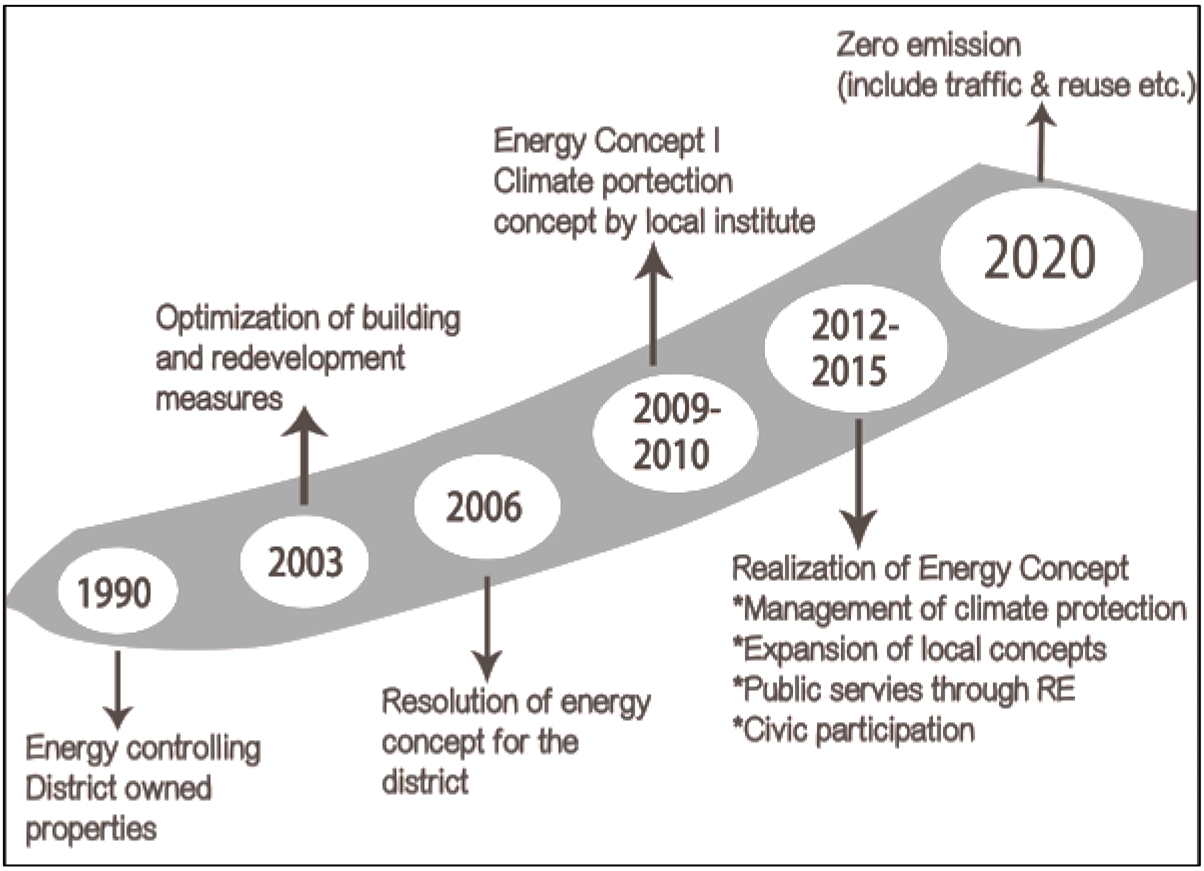

Figure 4-7 Conceptual Developments for Rhein – Hunsrück District's Urban Policies.

Source: (Fleck, 2013)

From 1999-2009, these efforts had led to nearly 25% reduction in heating demand, 5% reduction in electricity demand, and 26% reduction in water demand, greatly saved CO2 emission to a total of 5400 metric tons, approximating equal to 1.13 million euros in saving costs. By 2012, the heating demand was reduced by 26%, water demand by 34%, a total CO2 emissions reduction of 9,500 tons, with saved cost of around 2,000,000 euros. However, electricity demand increased by 1% (despite of doubling number of personal computers, introduction of air-conditioned server, introduction of catering and all-day-school; without additional measures of energy controlling, the increase would have amounted to 30%.) of the District's buildings by 2012 (Fleck, 2013).

A series of technologies have been implemented along the way, such as district heating grid, heating pumps, photovoltaic systems, passive houses, and biomass for heating. Environmental education center and extracurricular learning center are constructed for environmental education, which are also powered by the renewable energy produced locally. Their total electricity demand of the district was 473 million kWh in 2009, which was already 100% sufficient, in 2012, the percent grew to 149% (while the Germany national level was 22.9%) with hydropower 3.6%, winder energy 130.98% (national 7.7%), photovoltaic 12.10% (national 4.7%), biomass 6.17% (national 6.9%). What is really noticeable is that privately owned wind-and solar park were established on municipal areas: 14 wind power plants with a permanent rent of ca. 300,000 euro per year for a duration of 20 years plus a percentage share; solar power plant with a output of 2 MW: the plant will pass into the ownership of the municipality after 25 years.

Figure 4-8 Renewable Applications in Rhein – Hunsrück wind-and solar.

Pictures Source: (Fleck, 2013)

The District has also created several measures to help ensure that the community buys into the energy transition, that young people learn early about it, and that it gets implemented well. For example, there are extracurricular educational facilities where kids can learn about renewable energy and ecological stewardship. Additionally, a public relations campaign focuses on improving early age children’s eco-awareness and offering comprehensive information to the public with special marketing opportunities for citizen to contribute to the energy transition, communal solidarity, and electricity cost savings.

Lessons learned

To sum it up, the Rhein-Hunsrück District has made a comprehensive urban development plan with focus on energy efficiencies and application of renewable energy sources. Their implementation of eco-friendly technologies has maximized the local resources and conditions, and greatly encouraged the local stakeholder's participation in realizing this master plan. The results are not only benefiting their own residents, but also offer good references for China's low-carbon model town developments (Zou & Li, 2015).

4.5 Chapter Conclusion

Like the challenges once faced by the two case studies, China is currently facing promises as well as challenges that are unprecedented to any county in the world. Blindly following suits other countries' methods or approaches might not necessary lead to intended outcomes that are suitable and applicable for China. However, continuing the "business as usual" approach for urban development is destined and proved to fail. In an era when "low-carbon" becomes the "new norm," actively seeking best-practiced examples and experiences would help China to get on the right develop trajectory. More importantly, China needs to reinvent these ideas, concepts, and approaches based on its own geo-political conditions, and boldly pursue sustainable urbanization practices with the Chinese features.

The previously enlisted two cases have demonstrated two different approaches to developing urban areas into low-carbon eco-friendly cities of different population sizes, geographic features and political systems. The city of Kitakyushu in Japan indicates that both the national and local government would become the dominating factor for success or failure in a local region's transformation, especially for a traditional industrial city with population over the million. Through the government's political and financial supports, more of the local resources and stakeholders from the industries, academic and general public could be linked and integrated together to serve the overall goal of eco-city/town development. Such scale project would only be possible and better achievable with the government's policy and incentives, and local stakeholders' active involvement,

Germany's Rhein–Hunsrück District has transformed itself from a pure energy importer to an energy exporter by fully utilizing the local potentials for renewable energy production coupled with improvement of energy efficiencies and civic participations. For a city with the size of China's township level, Rhein–Hunsrück's approach could offer some insights to China's small sized cities or townships' low-carbon sustainable developments.

5 UNDERSTANDING SMART-CITY DEVELOPMENTS: A NEW FRAMEWORK AND ITS APPLICATION IN JAPAN

The Smart City (SC) concept is a new global trend for urban development, and is now gaining incremental popularity worldwide. Through an extensive literature review, it is found that despite lacking universal consensus, there have been two major streams of SC concepts with overarching strategies for comprehensive SC developments or with specific focuses on utilizing information and communication technologies (ICT) to improve the quality of life.

This chapter[28] summarizes the key features and components of smart cities and proposes a conclusive framework for smart cities that consist of double-objectives, six domains and two means for its realization. Furthermore, this chapter proposes customized indicator system based on the SC framework for measuring the “smartness” of the smart cities in Japan based on a case study of the City of Kitakyushu (or Kitakyushu City). This chapter provides some new insights to the methodological approaches adopted to assess the on-going smart city initiatives in Japan.

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[28] Based on this chapter, a journal paper is to be published as Zou, X., & Li, Y. (2016). “Recapitulating Smart City Concepts: A Proposed Framework and its Application in Japan”. *International Review for Spatial Planning and Sustainable Development*.

5.1 Chapter Introduction

5.1.1 Smart City: A Global Background

In recent years, the concept of “smart city” (SC) has been gaining incremental momentum particularly in the industrialized sphere. A consensus has seemingly been reached that the “business as usual” model for development is inherently not sustainable, thus alternatives of sustainable modes are desperately desired and needed. In the urban development realm, several mega-trends have emerged in the contemporary urban history. “Garden city”, “Eco-city”, “Low-carbon city” are some typical representations of urban development dynamism sought out though time, each addressing the needs and pursuits of urban development of their respective areas (Zou & Li, 2015a). The most recent one is “smart city”.

Mirroring the lack of universal accepted definition for “eco-city” and “low-carbon city” and other similar terminologies (Zou & Li, 2014), the concept of the smart city is neither internationally standardized nor universally defined. After thoroughly reviewing the currently available literature on smart cities including some frequently citied grey literature (conference papers, international organizational reports etc.), two streams of SC concepts and definitions can be identified. One stream focuses on developing SC to encompass broader scopes and multiple domains (such as infrastructures, energy, governance, economic growth and social life)(Angelidou, 2014; Lazaroiu & Roscia, 2012; Perboli et al., 2014); another stream clusters on specific aspects of SC development such as improving the quality of life (QoL) for residents via implementing information and communication technologies (ICT) in various aspects of daily life (Chourabi et al., 2012b; Cosgrave et al., 2013; Schuurman et al., 2012), both of which have their adherents and proponents amongst various stakeholders.

One of the early origins of the smart city concept is the “digital city”, referring to the utilization of various digital undertakings of the city, as can be seen in Amsterdam (Digital City Amsterdam), Helsinki (Virtual Helsinki) or Kyoto (Digital City Kyoto), just to name a few(Ishida & Isbister, 2000; Schuurman et al., 2012). Other umbrella terms including “wired city” or “intelligent city” have all addressed the technology-oriented smart city initiatives with different focuses (Paskaleva, 2011). Another parallel concept that is analogous to the smart city is “ubiquitous city”, also known as “U-city”. Considered as another model for future urban development that merges the physical and virtual spaces of cities, U-city aims to foster urban innovation and improve quality of life, with the emphasis inputs from the end users (Kwon & Kim, 2007) despite facing criticism over its preferences of specific clusters of end-users (such as youngsters) instead of all age groups (Choi, 2010; Schuurman et al., 2012).

The literal concept of “smart city” was firstly brought up by Mahizhnan (1999) to propagate Singapore, as an resource-scarce “Intelligent Island” with its vision and endeavor to embrace the new information technology (IT) for both boosting the economic growth and improving the quality of life for all people. In the years to follow, the SC concept gained incremental momentum, but criticism also emerged to question the validity of the actual existing smart cities (Shelton et al., 2015) due to its lack of precise definition. Additionally, some also critically question these smart cities “urban labeling” phenomenon as merely another variation of “entrepreneurial city” argued by Hollands (2008).

A more literal interpretation of SC focuses on the applications of smart sensors embedded with smart devices under the ICT scenario, where the internet of things (IoT) is envisioned to connect numerous sensors for more efficient and effective management of resources in cities (Perera et al., 2014) given the assumed roles sensors play in making “smarter” cities (Mitton et al., 2012). In this respect, consensus seems to have been reached by the many within IT domain of the academia, where the overarching goal of SC is to improve quality of life for the people and one major instrument of which is through “smart technology” implementation (mainly ICTs).

In this chapter, major concepts of both the identified streams in SC concepts are summarized, to promote a systematic understanding of what SC really is, and what its defining features are. Based on the reviewed literature, the author attempts to propose an encapsulating working definition of SC, to allow for better and more systematic assessment of smart cities. The author employs the Kitakyushu city of Japan, an internationally renowned innovative city for urban sustainability, to tailor-make an indicator system based on our proposed SC framework.

5.1.2 Smart city in Japan

Smart cities are defined by the Japan Smart City Portal[29] as "a new style of city providing sustainable growth and designed to encourage healthy economic activities that reduce the burden on the environment while improving the QoL for their residents". This program was initiated by Japan's Ministry of Economy, Trade and Industry (METI) and operated by New Energy Promotion Council since 2010, to promote a next generation of energy and social system.

Four project sites, namely, the City of Yokohama, Toyota City, Keihanna Science City and the City of Kitakyushu (also as Kitakyushu City for future reference) had been selected for testing smart grid- and smart city-related energy distribution and innovative social systems. These four project sites are the currently cutting-edge testing beds for numerous experiments to be implemented on a large scale in the future smart cities. Moreover, the Japanese government has actively promoted the participations of various stakeholders, particularly those of the general public, to share their ideas and thoughts for translating smart cities into reality.

5.1.3 Smart city in China

In China, smart city has become a national strategy in promoting industrialization and urbanization in the information era. A big impetus for developing smart cities in China is due to the cooperation between the government and IT companies (Li et al., 2015). In 2008, IBM started promoting the ideas of "Smarter Planet" as a shift of corporation strategy from hardware to software and subsequently held a number of smart city related forums with over

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[29] http://jscp.nepc.or.jp/en/index.shtml

200 mayors and 2000 city officials in China, due to its vast commercial potentials (Zhang & Du, 2011).

In 2002, the MHURD officially issued “Notice of Carrying out the National Smart City Pilot” and “National Interim Measures for Smart City Pilot” and approved 90 pilot SC projects, which turned to 193 in the year 2013. Smart cities have since then become a national strategy to advancing industrialization, informatization, urbanization and agricultural modernization in China. Chinese smart cities are more focused on dealing with technological issues without paying too much focus on seeking innovation, promoting creativity and entrepreneurship in the society (Li et al., 2015).

5.2 Smart city: their origin, concept and indicators

5.2.1 Smart city origins

The idea of smart city idea is neither new nor novel (Shelton et al., 2015, p.2). Its origin can be traced back to the “New Urbanism” in 1980s’ North America, the aim of which is “improving urban environment and the quality of life in cities by promoting communitarian ideas and limiting urban sprawl…”(Vanolo, 2013, p.887) until its ‘successor’, known as “Smart City” trend came forward in the late 1990s, wherein the U.S. government funded “smart growth” networks encapsulating a broad range of stakeholders like the Environmental Protection Agency (EPA), non-governmental groups and environmental organizations, professional associations and institutes, as well as developers of real-estate interests to revive urban America while benefiting the environment at large (Bronstein, 2009, p.27). Then the concept of “intelligent city” was applied to depict a new urban model of combining the urban sphere and techno-spheres to boost innovation, transition towards e-governance, and provide ICT infrastructure (Bronstein, 2009; Komninos, 2009). It was not long before the term “intelligent city” was embedded into “smart city” and used interchangeably thereafter.

5.2.2 Smart city concepts

As of now, the interpretations of what makes a city “smart” varies. The definitions of SC tend to focus on two domains, namely “soft domains” such as education, culture, policy innovations, social inclusion, governance; as well as “hard domains”, namely, infrastructures (buildings, energy grids etc.), natural resources, water and waste management, mobility and logistics (Albino et al., 2015, p.8). A rather thorough list of SC definitions has been compiled by Albino et al. (2015) which details the literature since 2000. Here I added some more SC definitions from the available literatures and digest and group these definitions based on their core meanings for a compressed view (refer to table 5-1). By vertically examining these established SC concepts, I have summarized two major components of a smart city, namely the goals for a smart city and the means to realize them. Two major goals can be identified from the listed concepts, which contain double-fold parallel pursuits: to improve quality of life and to pursue sustainable urban development. The means for their realizations are mainly though the “smart” technology implementation, mainly in the form of (but not limited to) information and communication technology.

The industry sectors have also been actively riding on the forefront of this “smart city” tide. The international players like IBM, Cisco Systems. Siemens AG and Hitachi Group have all come up with their “solutions” for helping the local stakeholders to realize their smart city goals, from specific technology products to whole package of making a community smart.

In terms of what constitutes a smart city, Giffinger et al. (2007b) first identified four SC features, namely, industry, education, participation and technical infrastructure, that were later updated into six SC characters or components: smart economy, smart mobility, smart environment, smart people, smart living and smart governance (Giffinger & Gudrum, 2010). Lombardi et al. (2012) delineated a range of urban life aspects which can be associated with the previously mentioned components in terms of industry for smart economy, education for smart people, e-democracy for smart governance, logistics & infrastructures for smart mobility, efficiency and sustainability for smart environment, security & quality for smart living. Other specific SC dimensions have been identified by literatures (Barrionuevo et al., 2012; Kourtit et al., 2012; Mahizhnan, 1999; Nam et al., 2011a, 2011b), which are reviewed by Albino et al. (2015, p.10) to share the following common grounds:

- Network connected infrastructures which enable political, social and cultural developments
- Business-led urban development to promote urban sustainable growth
- Engagement of urban stakeholders so as to develop social capitals
- Preserve natural environment for the future

As a new development form that follows “eco-city” and “low-carbon city”, there have been approximately 143 designated or self-proclaimed smart city projects, where Asia and Europe saw the most in numbers (50 and 47 projects respectively), followed by North America (35 projects), South America (10 projects) and Africa (10 projects) (Lee et al., 2014). However, some of the projects have multiple titles such as the renowned example of Masdar City, which is known to the world as “eco-”, “low-carbon” and “smart”. Other famous smart cities include (but not limited to) Songdo smart city in South Korea, Taoyuan city in Taiwan, Barcelona, Amsterdam, Berlin in Europe, Manchester, Edinburgh and Bath in the UK, California, Dan Diego and San Francisco in the US, Ottawa and Quebec in Canada (Albino et al., 2015, pp. 13-14).

Table 5-1 Concepts or Definitions of Smart City Reviewed

Definition	Source
“Smart city as a high-tech intensive and 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 an increased quality of life.”	(Bakici et al., 2012)
“Being a smart city means using all available technology and resources in an intelligent and coordinated manner to develop urban centers that are at once integrated, habitable, and sustainable.”	(Barrionuevo et al., 2012)
“A city is smart when investments in human and social capital and traditional (e.g. transport) and modern (e.g. 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., 2011)
“Smart cities will take advantage of communications and sensor capabilities sewn into the cities’ infrastructures to optimize electrical, transportation, and other logistical operations supporting daily life, thereby improving the quality of life for everyone.”	(Chen, 2010)
“Two main streams of research ideas: 1) smart cities should do everything related to governance and economy using new thinking paradigms and 2) smart cities are all about networks of sensors, smart devices, real-time data, and ICT integration in every aspect of human life.”	(Cretu, 2012)
“A city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-determined, independent and aware citizens. Smart city generally refers to the search and identification of intelligent solutions, which allow modern cities to enhance the	(Giffinger et al., 2007b)

quality of the services provided to citizens.”	
“A smart city, according to ICLEI, is a city that is prepared to provide conditions for a healthy and happy community under the challenging conditions that global, environmental, economic and social trends may bring.”	(Guan, 2012)
“A city that monitors and integrates conditions of all of its critical infrastructures including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens.”	(Hall, 2000)
“A city 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)
“(Smart) cities as territories with high capacity for learning and innovation, which is built into the creativity of their population, their institutions of knowledge creation, and their digital infrastructure for communication and knowledge management”	(Komninos, 2011)
“Smart cities are the result of knowledge-intensive and creative strategies aiming at enhancing the socio-economic, ecological, logistic and competitive performance of cities. Such smart cities are based on a promising mix of human capital (e.g. skilled labor force), infrastructural capital (e.g. high-tech communication facilities), social capital (e.g. intense and open network linkages) and entrepreneurial capital (e.g. creative and risk-taking business activities).”	(Kourtit and Nijkamp, 2012)
“Smart cities have high productivity as they have a relatively high share of highly educated people, knowledge-intensive jobs, output-oriented planning systems, creative activities and sustainability-oriented initiatives.”	(Kourtit et al., 2012)

“Smart city [refers to] a local entity - a district, city, region or small country, which takes a holistic approach to the employ[ing] of information technologies with real-time analysis that encourages sustainable economic development.”	(IDA, 2012)
“A community of average technology size, interconnected and sustainable, comfortable, attractive and secure.”	(Lazaroiu and Roscia, 2012)
“The application of information and communications technology (ICT) with their effects on human capital/education, social and relational capital, and environmental issues is often indicated by the notion of smart city.”	(Lombardi et al., 2012)
“A smart city infuses information into its physical infrastructure to improve conveniences, facilitate mobility, enhance efficiency, conserve energy, improve the quality of air and water, identify problems and fix them quickly, recover rapidly from disasters, collect data to make better decisions, deploy resources effectively, and share data to enable collaboration across entities and domains.”	(Nam et al., 2011a)
“Creative or smart city experiments … aimed at nurturing a creative economy through investment in quality of life, which in turn attracts knowledge workers to live and work in smart cities. The nexus of competitive advantage has … shifted to those regions that can generate, retain, and attract the best talent.”	(Thite, 2011)
“Smart cities of the future will need sustainable urban development policies where all residents, including the poor, can live well and the attraction of the towns and cities is preserved…. Smart cities are cities that have a high quality of life; those that pursue sustainable economic development through investments in human and social capital, and traditional and modern communications infrastructure (transport and information communication technology); and manage natural resources through participatory policies. Smart cities should also be sustainable, converging economic, social, and environmental goals.”	(Thuzar, 2011)
“A smart city is understood as a certain intellectual ability that addresses several innovative socio-technical and socio-economic aspects of growth. These aspects lead to smart city conceptions as “green” referring to urban infrastructure for	(Zygiaris, 2012)

environment protection and reduction of CO2 emissions, “interconnected” related to the revolution of broadband economy, “intelligent” declaring the capacity to produce added value information from the processing of city’s real-time data from sensors and activators, whereas the terms “innovating”, “knowledge” cities interchangeably refer to the city’s ability to raise innovation based on knowledgeable and creative human capital.”	
“The use of Smart Computing technologies to make the critical infrastructure components and services of a city, which include city administration, education, healthcare, public safety, real estate, transportation, and utilities—more intelligent, interconnected, and efficient.”	(Washburn et al., 2009)
“Smart cities are all urban settlements that make a conscious effort to capitalize on the new Information and Communication Technology (ICT) landscape in a strategic way, seeking to achieve prosperity, effectiveness and competitiveness on multiple socio-economic levels”	(Angelidou, 2014)
“Smart cities should propose a holistic vision of future communities where new technological tools, services and applications are integrated in a unique platform, providing interoperability and coordination between these several sectors”	(Perboli et al., 2014. p.470)
“Smart cities initiatives try to improve urban performance by using data, information and information technologies (IT) to provide more efficient services to citizens, to monitor and optimize existing infrastructure, to increase collaboration among different economic actors, and to encourage innovative business models in both the private and public sectors.”	(Marsal-Llacuna et al., 2015)

5.3 Smart City Indicator Systems

When it comes to the evaluation of smart cities, a number of international organizations, institutes and scholars have competed in establishing international norms or standards. The Austrian Climate and Energy Fund (KLIEN) initiated the project “Scientific Evaluation of the Smart-Cities-Initiative” which aims to scientifically design and evaluate smart city initiatives[30]. The International Electronic Commission (ICE)’s System Evaluation Group (SEG) proposed to establish an SC scope and standards according to their definition, in cooperation with the International Organization for Standardization (ISO)[31]. And ISO also has their town SC standards for definition and evaluation entitled “Smart community infrastructures – Principles and requirements for performance metrics” (ISO/TS 27171:2015)[32]. They have surveyed and developed a set of key performance indicators (KPI) with references to three sets of established indicators, namely, “Global City Indicators”, “Green City Index series” and “Smart City realized by ICT prosed by Fujitsu” (ISO, 2014, p7).

A “Smart City Ranking” was conducted by Giffinger et al. (2007a) to compare medium-sized cities in Europe, the framework of which has provided useful insights to the later development of smart city measurements with an index of six characters consisting of 31 factors with a total of 74 subsequent indicators. Another smart city model was proposed by Lazaroiu & Roscia (2012) with four criteria (smart economy, smart environment, smart energy and mobility, and smart governance), where fuzzy logic was applied to calculate the weights of the enlisted indicators as a supplement to indicator systems applied in “Smart City ranking”. Their results indicate that the smart city is particularly influenced by sustainable, innovative and safe public transportation (Lazaroiu & Roscia, 2012,p. 330). However, they fail to illustrate the affiliating criteria that the indicators should be categorized into (refer to Table 5-2).

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[30] .http://www.smartcities.at/activities/scientific-evaluation-of-the-smart-cities-initiative/

2.http://www.iec.ch/dyn/www/f?p=103:186:0::::FSP_ORG_ID,FSP_LANG_ID:10330,25

32.https://www.iso.org/obp/ui/#iso:std:iso:ts:37151:ed-1:v1:en

Other rankings such as the Global Power City Index (created by the Japanese Institute for Urban Strategies), the Smarter Cities Ranking (conducted by the Natural Resources Defense Council of US) and a host of other organizations like the Smart Cities Council, business groups like Arcadis (others include the aforementioned mentioned IBM, Siemens, Cisco, Hitachi etc.) and individuals have proposed different ways of measuring or evaluating cities with selected goals and targets. Idowu & Bari (2012) proposed a generic development framework that can help to develop and deploy services in smart city and more recent published report by Barranco et al. (2015) commissioned by EU offers a broader framework to evaluate and assess the urban developments with time series and geographical features of urban areas. Analytical models have been conducted by Lombardi et al. (2012) to measure the performance of smart cities in general, which offers insights to policy-making with identified indicators. Individual evaluation model has been proposed by Lv (2012) for assessing the smart city development of Tianjin city as specific case study.

Table 5-2 Digest of smart city indicator systems

Dimensions/Criteria/Features	**Structures**	**Sources**
Smart Economy (Innovative spirit, entrepreneurship, economic image & trademarks, flexibility of labor markets, international embeddedness) Smart People (Level of qualification, affinity to life long learning, social and ethnic plurality, flexibility, creativity, cosmopolitanism/open-mindedness, participation in public life) Smart Governance (Participation in decision-making, public and social services, transparent governance) Smart Mobility (Local accessibility, inter-/national accessibility, availability of ICT-infrastructure, sustainable…transport systems) Smart Environment (Attractiveness of natural conditions, pollution, environmental protection, sustainable resource management) Smart living (Cultural facilities, health conditions, individual safety, housing quality, education facilities, tourism attractiveness, social cohesion) Note: sub-indicators not included in this table	6 characters 31 factors 74 indicators[1]	(Giffinger et al., 2007a)
Smart economy, Smart environment, Smart energy and mobility, Smart governance (Pollution, innovative spirits, CO2, transparent management, soiled waste separation, education facilities, health conditions, sustainable, innovative and safe public transportation, pedestrian areas, cycle lanes, green areas, production of municipal solid waste, GWh household, fuels, political strategies & perspectives, availability of ICT-infrastructure, flexibility of labor market)	4 criteria 18 indicators	(Lazaroiu & Roscia, 2012)
People (Transport infrastructure, health, education, income inequality, work-life balance, the dependency ratio, green spaces within cities) Planet (City energy consumption, renewable energy share, recycling rates, greenhouse gas emissions, natural catastrophe risk, drinking water, sanitation, air pollution) Profit (Perfromance from a busines perfective, combining measures of transport infrastructure <rail, air, other publica transport and commuting time>, ease of doing business, the city’s importance in global economic networks, proerty and living costs, GDP per	3 criteria 21 indicators	(Arcadis, 2015)

capita, energy efficiency)		
Economy (Market size, market attractiveness, economic vitality, human capital, business environment, regulation & risks) Research & development (Academic resources, research background, research achievement) Cultural interaction (Trendsetting potential, cultural resources, facilitiess for visitors, attractiveness to visitors, volume of interaction) Livability (Working environment, cost of living, security & safety, living environment, living facilities) Environment (Ecology, pollution, natural environment) Accessibility (International transportation network, international transportation infrastructure, inner-city transportation services, traffic convenience)	6 functions 26 indicator groups 70 indicators	Global City Power Index 2014[33]
Network Facilities (10) Information Facilities (4) Environment (8) Building (4) Energy & Natural Resources (7) Innovation (5) Knowledge Economy (5) Governance (5) Transportation (6) Security and Safety (7) Sanitation (3) Healthcare (4) Education & Training (3) Openness (3) Participation in Public Life (3) Convenience & Comfort (17)	16 criteria 94 indicators	(ISO, 2014)
Environment (Smart buildings, resources management, sustainable urban planning) Mobility	6 dimensions 18 working areas 46 indicators[1]	Smart Cities Council[34]

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[33] http://www.mori-m-foundation.or.jp/gpci/index_e.html

[34] http://smartcitiescouncil.com

(Efficient transport, multi-modal access, technology infrastructure)
Government (Online services, infrastructure, open government)
Economy (Entrepreneurship & innovation, productivity, local & global connection)
People (Inclusion, education, creativity)
Living (Culture & well-being, safety, health)

Note: Some of the sub indicators are not listed for the sake of space

All of the reviewed indices consist of different themes or subthemes, categorization of indicators with different ranking results. It is my opinion that to have some overarching and all-encapsulating indexes or indicator systems for smart city measurement is not viable at the current infant stage of smart city development. Assessment or evaluation would make more sense within a particular system boundary with a properly defined concept, development goals and approaches. Developing tailor-made mechanisms either for policy or framework would work better for the regional urban development in a smart manner.

5.4 Proposed Smart City Framework Based On the Literature Review

After thoroughly reviewing concepts, dimensions, frameworks and indicator systems of the smart cities to the best of my knowledge, I have identified dual objectives or goals manifested in most of the reviewed articles, namely, 1) to improve the quality of life of the local citizens, and 2) to pursue the sustainability for urban growths and developments. The major instruments to achieve the objectives or goals are though the innovation and implementation of “smart” technologies, such as ICT, sensors networks etc. and the involvement of the major stakeholders from the industry, academia and government (triple helix model). The main constitution of SC entails double domains, both “soft” and “hard”. Soft domains include (but are not limited to) dimensions such as “economy”, “governance”, “people & living”; hard domain includes (but is not limited to) dimensions like “infrastructure”, “energy & mobility”, “environment” (refer to Figure 5-1).

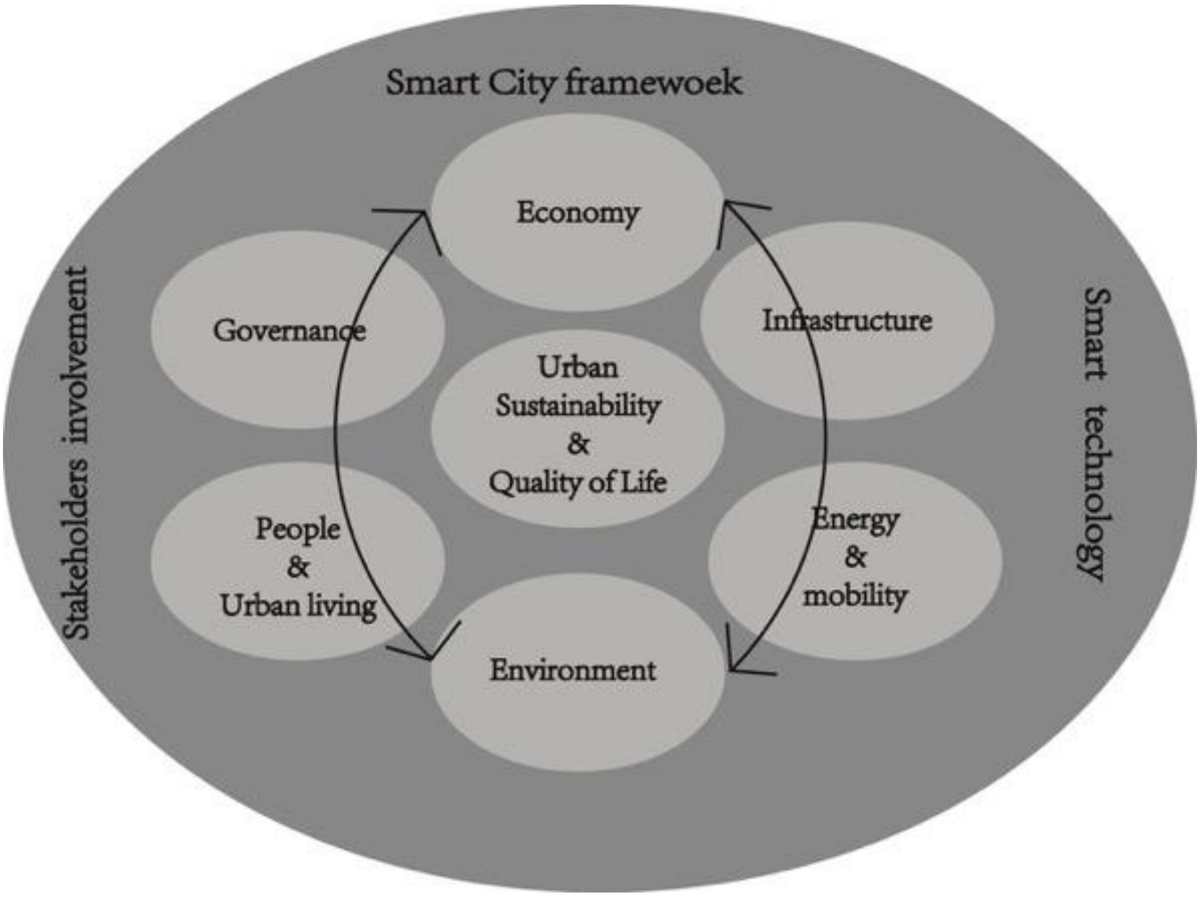

Figure 5-1 A Conceptual Framework of Smart Cities

In this session, I have obtained a rather comprehensive understanding of smart cities by understanding the objectives and goals of the smart cities, the instruments for their implementation and their major contents or domains of developments. This proposed framework illustrates the reviewing outcome and is used as the theoretical foundation for the subsequent establishment of a smart city index for a selected case study city in Japan

5.5 Smart City Evaluation In Japan: Framework Application In Kitakyushu

5.5.1 Selection of case study: the City of Kitakyushu

The city of Kitakyushu is located in the north of Kyushu island in Japan, with a territory of over 491 km^2 and a population of 957,600. From the 1950s until the 1970s, this heavy industrial city of iron manufacturing was severely polluted, especially in the air and water. The Dokai Bay of the city was so contaminated that it gained the nickname of “Sea of Death”, and public health suffered profoundly due to heavy pollution (refer to the photo attached in Table 5-3). Through decades of continuous and strenuous efforts in environmental protection and sustainable development, the city has restored its blue sky and clean water, and has been awarded both domestically and internationally with, for example, “Japan’s Eco-model City Award”, “United Nations Global 500 Role of Honor Award”, “Earth Summit: UN Local Government Honors” (Maeda, 2010), just to name a few.

Table 5-3 Selected information of Kitakyushu City

Territory	491.95 km2 (by April, 2015)
Population	957,597 (by April, 2015)
Location	Fukuoka Prefecture, northeast of Kyushu area, southeast of Japan.  Picture source: Wikipedia

Environmental conditions of Kitakyushu's bay area (past & present)	 Smoggy sky (1960s)  Blue sky restored (present day)  Dokai Bay once called the 'Sea of Death' (1960s)  Dokai Bay regained it's original beauty (present day) Source: (Giffinger et al., 2007a)
Smart City (Eco-Town) Project	Project location: The Higashida area in Yahata-Higashi ward Area coverage: Approximately 1.2 km2 Participating households: 225 (as of August 2012) Participating workplaces: 50 (as of August 2012) Smart meters installed: 225 (as of August 2012) Technology applied: Storage batteries 800kW; Photovoltaic (PV): 400kW; Fuel cells 110 kW

The Smart City (Eco-Town) Project in Kitakyushu city encompassing the entire eastern section of the Hibiki Landfill Area was first approved by Japan's then Ministry of Industrial Trade and Industry (MITI) in 1997, which later became the Ministry of Economy, Trade and Industry (METI) in 2001. METI greatly promoted this project and offered subsidies for the constructions of infrastructure and marketing. There are two stages of the project with the overall aim of promoting zero emissions though re-utilizing the waste of the local industries, contributing to the 3R (Reduce, Reuse and Recycle), society development of Japan with the first stage (1997-2002) focusing on the "Recycle" and the second stage (2002-2010) focusing on "Reuse".

The overall strategy is to link together academic research, demonstrative and applied research, and the private sector of the local industries, to have jointly efforts of all these components working together. The successful outcomes of this smart city project of Kitakyushu city have made an international brand for Japan's local practices of eco-city initiatives. Moreover, in terms of financial value, a total 50,200 million Japanese yen was invested, of which 7% came from the private sector, and over 1000 jobs were created. An accumulated 109,300 million yen was invested from 1998 to 2003 (Zou & Li, 2015a).

Besides the government and institutions, the industrial sector has also actively engaged in the “smart city business” given their advances in ICT. The Hitachi Group established a Smart City Business Management Division in 2010 to provide “smart city solutions that combine Hitachi’s wide range of products and solutions with its extensive past experience.” They also participated in the development of Yokohama Smart City project initiated by METI. Their major international competitors include CISCO and IBM etc.

5.5.2 Proposed Smart City Index for Kitakyushu City

It is imperative to have a case study site where the concluded smart city framework can be applied. As one of the four chosen national pilot project sites for smart city development, Kitakyushu City is known for its eco town development and smart community project[35]. This city is chosen as a case study for its relevance, physically proximity and data accessibility for the study. I participated in workshops and conventions held by the local stakeholders to seek their inputs regarding the concerned themes and indicators for the proposed smart city index. Also, I have conducted several field research trips to local governmental bureaus and industries, where good professional relationship with local NGOs and NPOs were developed. These are the reasons why Kitakyushu City is chosen.

As is seen previously, Kitakyushu has made tremendous and continuous efforts to pursue urban sustainability through government initiatives, civil participation, and technological innovation and implementation over the past decades. To fill the gap of not having a universal measurement yet for the comprehensive smart cities development in Japan, I have proposed a set of indicators based on the framework previously proposed for a rather holistic measurement and evaluation of such smart city programs and initiatives in

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[35] http://jscp.nepc.or.jp/en/kitakyushu/index.shtml

Japan. Hopefully, this will bring some more clarity and insights for policy makers and city planners as well as scholars and students of the related fields of study. I advocate finding a way to select the most suitable and manageable ones within the already existing pools of indicators under our concluded framework, which is believed to have summarized the major features constituting a smart city suggested by literatures and case studies worldwide.

I have assigned six dimensions for the smart city indicator systems of Kitakyushu city with the double goals of pursuing urban sustainability and improving the quality of life (refer to Figure 5-1), including “Governance”, “Economy”, “People & Urban living”, “Infrastructure”, “Energy & Mobility”, “Environment”. Under each dimension, I have conducted a selection based on mainly the relevance, suitability and availability of indicators. The indices of existing indicators include the sustainable indicator index proposed by Dhakal (2012) of the Institute of Global Environmental Strategies (IGES), a Japanese government initiated public policy research institute, the Asian Green City Index proposed by the Economist Intelligence Unit (2011), and the Smart City Index established by Giffinger et al. (2007b). In my opinion, sustainable cities and green cities are inherently “smart” cities; therefore major preference is given to the first two indices for the indicator selections. I have included 18 aspects under the 6 dimensions with a total of 36 indicators. The detailed descriptions of each aspect and its affiliated indicators are shown in the following table (refer to Table 5-4).

However, not all the indicators from IGES are suitable matches within the framework, and a finer selection is conducted based on the indicators reviewed in the previous section, considering content relevance, suitability and data availability.

Table 5-4 Proposed smart city indicator system of Kitakyushu City

Dimensions	**Aspects**	**Indicators**
Governance	Transparency & Management	Perception of transparency of bureaucracy Perception of fight against corruption Monitor its environmental performances
	Civil participation	City representatives per resident Female city representatives Public participation in environmental decision-making
Economy	Innovation	% of budget of local government allocated for environment R&D expenditure in % of GDP
	Sustainable development	Use of electricity per GDP Use of water per GDP
	Labor & Capital	Gross city product per capita Households below poverty line
People & Urban living	Human health	Number of doctors per 1000 population Number of hospitals per 1000 population
	Institutional & Social capacity	Number of environmental staffs in city government per 100 thousand population % of industries complied with emission control regulations % of vehicles compliant with emission control regulations Adult literacy rate
Infrastructure	Buildings	Energy consumption of residential buildings Energy-efficient building standards
	Land use	Green spaces per capita
	Smart grid	Accessibility of smart grid
Energy & Mobility	Renewable energy	Share of renewable energy in total energy use
	Energy efficiency	CO2 per capita from energy use
	Sustainable transportation	Green mobility share E-vehicle in commercial vehicle shares
Environment	Air quality	SO2 concentration TSP concentration
	Water availability	% of population with access to adequate and clean water Water renewable rate of the source

	Water quality	BOD concentration of inland water bodies COD concentration of the coastal water % of green area in the total land use
	Urban green	% of green area in the total land use
	Waste & Waste water	Per capital waste generation % of total solid waste collected % of total waste water treated

There are some limits of this study and proposed index though. Given the current on-going status of the research, I have maintained the size of indicators within a manageable 2-5 for each aspect, and 2-5 aspects for each dimension in this paper. Moreover, I have not assigned any weighting, aggregation or conduct ranking with the indicators for the time being. A follow-up updating of both indicator quality and quantity with proper weighting methodology is to be conducted in the follow-up steps of this research.

5.6 Chapter Conclusion and Discussion

Under the current trends of rapid and unceasing urbanization, to cope with the various “urban ills”, wide-scale urban trends such as “garden city”, “green city”, “eco-city”, “low-carbon city” have been seen since the late 19th century onward, with the latest being “smart city” amongst others. Yet hardly any of those mega-trends has resulted in universal paradigm or model that can be applied without localization or customization based on regional features or local situations.

This paper has reviewed the major literatures of smart cities in terms of their multi-faceted concepts, constitutions and indicator systems in an attempt to recapitulate an encapsulating and comprehensive framework that can be applied within the local context. As a result, I have proposed a framework with twofold objectives (urban sustainability & improvement of QoL) with 6 constituting dimensions. Based on this diagram, I have established a framework with 18 aspects and 36 supporting indicators from the existing indexes of sustainable, green and smart cities for the up-coming measurement and evaluation of the case study Japanese city of Kitakyushu.

Discussion: Many scholars, particularly from the computer science discipline, consider the implementation of ICTs as the sole component of smart cities. And the others understand the smart cities as new approaches to solve the existing urban problems and seemingly paradoxical conflicts between people's life quality and urban sustainability, which I tend to agree more with.

In my opinion, all the eco-cities and low-carbon cities that contribute to urban sustainability are inherently "smart" cities. Thus, developing or measuring new smart cities shall encompass the features from the previous urban development models, and ICTs are but one of the core elements. Novel frameworks or sets of indicators are sometimes less effective and pragmatic than tailor-made assessment tool set up for specific vision of smart cities at a local setting.

Despite lacking universal SC definitions, common goals and features contributing to SC are indeed observable. It is necessary to develop a method or approach, instead of explicit index, that can offer more practical references to policy makers, urban planners and stakeholders to pursue sustainability in city developments.

6 A NEW EVALUATION APPROACH FOR SUSTAINABLE CITIES: FROM SMART CITY CONCEPT TO INDICATOR WEIGHTING

In this chapter, further improvement is made to the proposed smart city conceptual framework as outlined in Chapter 5. Under this framework, I have further refined the selection of indicators based on the inputs from the stakeholders in the City of Kitakyushu. Revisions and modifications have been made to the proposed index. The Analytical Hierarchy Process (AHP) is applied in the weighting of indicators by an expert survey. Finally an integrated approach is developed as the outcome.

This integrated approach is found to be highly customizable and adoptable for potential applications to other urban development models in different contexts for both framework development and index composition. The findings of this study would contribute to a more insightful understanding of the smart city and its evaluation for policy makers, academia, urban managers, and practitioners. Furthermore, this integrated approach can also be adapted to understand and evaluate sustainable cities in general with local inputs.

6.1 Chapter Introduction

Several global trends of sustainable cities have emerged in recent human history as responses to an array of geo-social challenges brought with the technology-led productivity boost and population increase. “Eco-city”, “Low-carbon City” are some featured examples addressing the urban challenges of their respective periods. With the rapid advancement of information and communication technology (ICT), the notion of “Smart City” is at the forefront of sustainable urban development trends.

Despite its global phenomenal scale, a concise definition for smart cities (SC) with universal consensus is yet to be distilled. This is reflected in the diversity of definitions and interpretations of previous global trends of eco-cities and low-carbon cities. Myriad research and studies have been done in regard to the conceptualization of smart cities. I have conducted a systematic review of the highly regarded literature to obtain insights into what constitutes a “smart city” and its common features, based on which I have generalized a SC conceptual framework and offered an interpretation of smart cities.

Meanwhile, as an important component for analysis, evaluation and realization of SC concepts, the indicator system or index has not been fully addressed (Lombardi, 2011). Even though similar indicator systems or indices of urban sustainability have been developed by various parties, many of these focus on ranking cities or projects without tackling the deeper purpose of having indicators: to facilitate better decision-making and evaluation of objectives. Thus, a further step is taken for this study towards developing a SC index based on the proposed conceptual framework and understanding of smart cities as a feature necessary for SC development.

As an equally important segment of sustainable city index composition, the selection of a proper weighting mechanism for indicators would better guide decision-makers and key stakeholders with prioritization, quantification and performance evaluation of SC projects and development. The Analytical hierarchy process (AHP), a novel approach to imprecise assessment and decision environment (NAIADE), and Multi-attribute utility theory (MAUT) are some commonly used methods for decision-making (De Montis et al., 2000). I have applied the AHP method to further weight the indicators under the proposed index, contributing to an integrated approach for packaging these core elements into the smart city framework. The outcomes of this study contribute to some more instrumental insights and referable methodologies regarding smart cities, and relevant urban models for academics, practitioners, policy makers and other stakeholders.

6.2 Weighting of Indicators by AHP

Indicators are used widely in various aspects and domains and for different stakeholders, particularly in the process of decision-making (United Nations, 2007). Indicators need to be placed into conceptual frameworks in order to have a clear focus and objectives for measurement. Some commonly employed frameworks for indicators include "driving force-state-response frameworks", "Issue-or theme-based frameworks", "Capital frameworks", "and Accounting frameworks", amongst which "Issue-or theme-based frameworks" are commonly adopted for sustainability indicator development due to their ability to link indicators to policy process and targets, and also for their flexibility in adjusting to new priorities and policy targets (United Nations, 2007).

The Analytical Hierarchy Process (AHP) was first developed by Saaty (1980) as a multiple criteria decision-making tool. It is a methodology based on an Eigenvalue approach to the pair-wise comparisons, to calibrate a numeric scale for the measurement of both quantitative and qualitative performance (Vaidya & Kumar, 2004). It has been widely applied in numerous fields such as software development (Kengpol & O'brien, 2001; Lai et al., 2002) and project management (Harbi, 2001) as selection tools; supply chain evaluation (Akarte, 2001), hierarchy composition (Fogliatto & Albin, 2001), process & quality assessment (Cagno et al., 2001; Forgionne & Kohli, 2001) as evaluation tools; cost & benefit analysis (Chin et al., 1999; Tmmala et al., 1997); allocations (Badri, 1999; Ramanathan & Ganesh, 1995); planning & development and many other fields including "prioritization and ranking", "decision making", "forecasting" etc. (Vaidya & Kumar, 2004, p.12-16).

AHP is also widely adopted for indicator weighting and evaluation. Tong et al. (2012) proposed an AHP based water-conservation indicator system for the textile industry in China. Bozbura and Beskese (2007) used AHP to prioritize indicators for measuring organizational capital. Indicators of other sectors include but are not limited to construction, transportation, tourism, and environment (Awasthi & Omrani, 2009; Kil et al., 2016; Wang et al., 2016). Although the AHP based method has also been used for city performance evaluation (Jourtit et al., 2014), there is not yet any specifically customized AHP application in indicator weighting for smart cities, to the best of our knowledge.

6.3 Methodology

I have followed three major steps for developing this weighted SC index, each of which can be further divided into three sub-steps. For the first step, I have defined our scope and established a working conceptual framework for smart cities. This has been done by conducting a thorough literature survey of the mainstream definitions or concepts of smart cities and analyzing them under a policy analysis framework. Based on our analysis of commonalities presented in the literature, I then propose an integrated and inclusive concept for a smart city (refer to Figure 6-1).

For the second step, I have developed a customized SC index based on the proposed SC concept. I first identified the potential indicator pools for selection based on reference and availability. Then an initial selection of indicators is conducted according to the proposed conceptual SC framework, with links to references, data availability and operability or manageability. I then integrated the selected indicators into a complete SC index.

For the third step, the customized SC index is weighted using the analytical hierarchy process (AHP). First a group of experts and professionals is identified based on our domains (themes) of indicators given their professional knowledge or profound experience. Then their inputs are surveyed with pair-wise comparison of indicators. Finally, the survey data is collected and applied with the AHP analysis, for a weighted SC index.

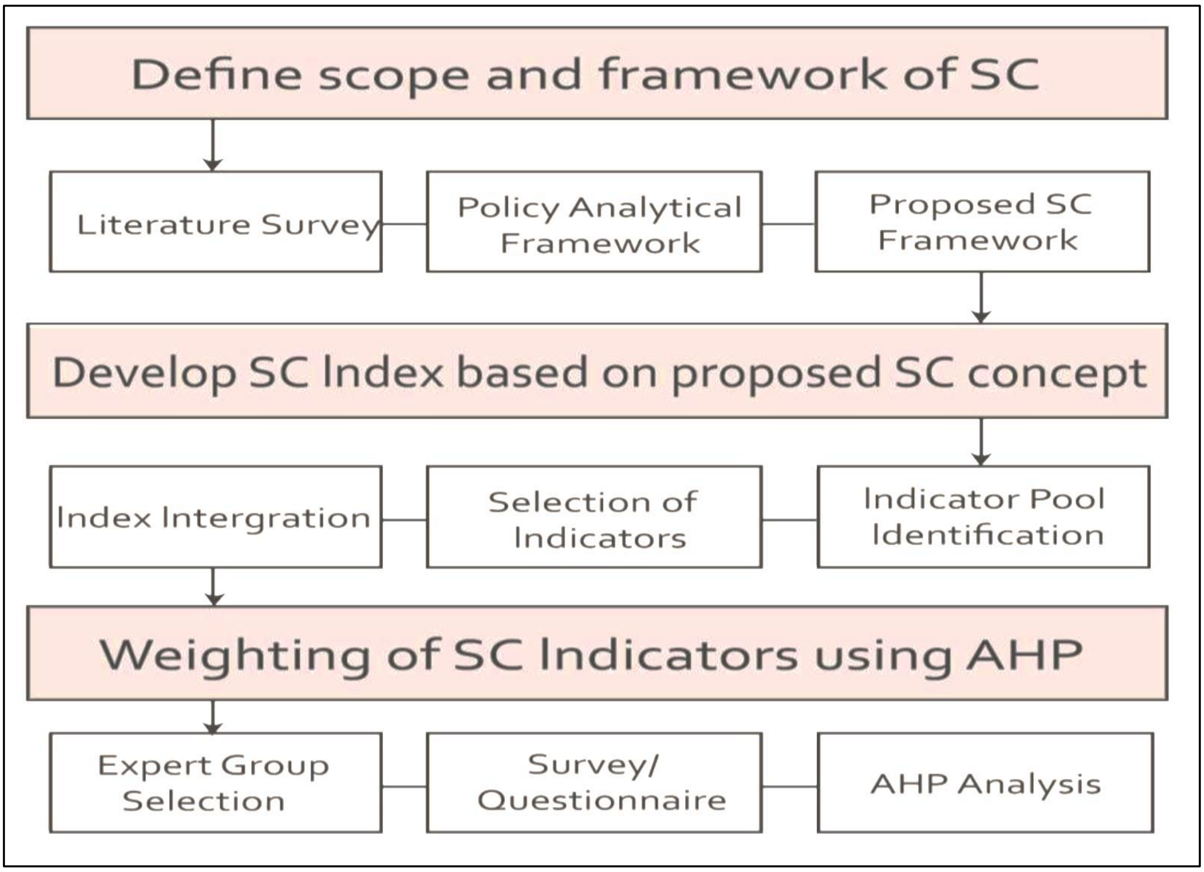

Figure 6-1 Integrated Approach for SC Concept framework, its SC Index and Weighting of Indicators.

6.3.1 A Smart City Conceptual Framework

Smart city initiatives are the realization of urban political agenda guided by urban policies. Therefore, it can be further decomposed, analyzed and evaluated. Hall (1993) regards policy to consist of goals, techniques or instruments and settings. Bennett (2009) further declassified policy components into policy goals, contents, instruments, outcomes and styles. Additional components have also been proposed such as policy concepts, attitudes, administrative structures etc. (Dolowitz, 1997; Larmour, 2002; Pierson, 1997). Liu and Qin (2016) have systematically analyzed the Chinese low-carbon city initiatives in the manufacturing, transportation and building sectors by deconstructing the low-carbon frameworks in to goals, contents, and instruments.

I adopted the analytical framework for the smart city analysis as demonstrated in Figure 6-2. Smart city concepts are then deconstructed into three components, namely, smart city objectives, smart city contents, and smart city instruments. SC objective(s) refers to the goals and objectives that are pursued within this concept or policy initiative; SC content(s) includes the major domains, themes and categories to be included in the establishment of smart cities; SC instrument(s) pertain to the means or method to realize the objectives and goals of smart cities.

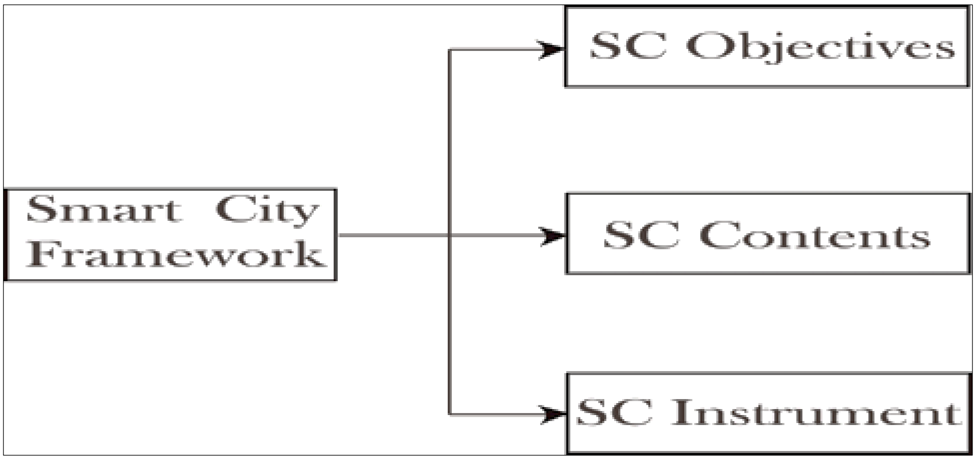

Figure 6-2 Analytical frameworks for smart city concepts

Through a qualitative topological analysis of 23 frequently citied smart city concepts under the analytical framework of goals, contents and instruments, I have come to the following conclusions:

- There are two most common objectives or goals that are pursued by smart cities. One focuses on improving quality of life, while the other one pursues sustainable urban development;
- Several themes or sectors are frequently mentioned by many sources. Despite differences in the exact terms, these theme or sectors can be classified into hard domains and soft domains. Soft domains entail sectors such as governance, human lives, urban living, economic and social conditions whilst the hard domains encompass infrastructure, energy, mobility and traffic, ambient environment etc.

- There are mainly two major instruments for realizing the SC goals and objectives: the implementation of technology and the involvement of stakeholders.

Thus, a conceptual framework for smart city is concluded as:

A city pursues double fold goals of improving life qualities meanwhile realizing urban sustainability; major contents include both hard and soft urban domains such as (but not limited to) “Governance”, “People & Urban Living”, “Economy”, “Infrastructure”, “Energy & Mobility”, “Environment”; the active involvement of stakeholders and implementation of information and communication technologies are the major instruments for implementation, as demonstrated in Figure 6-3.

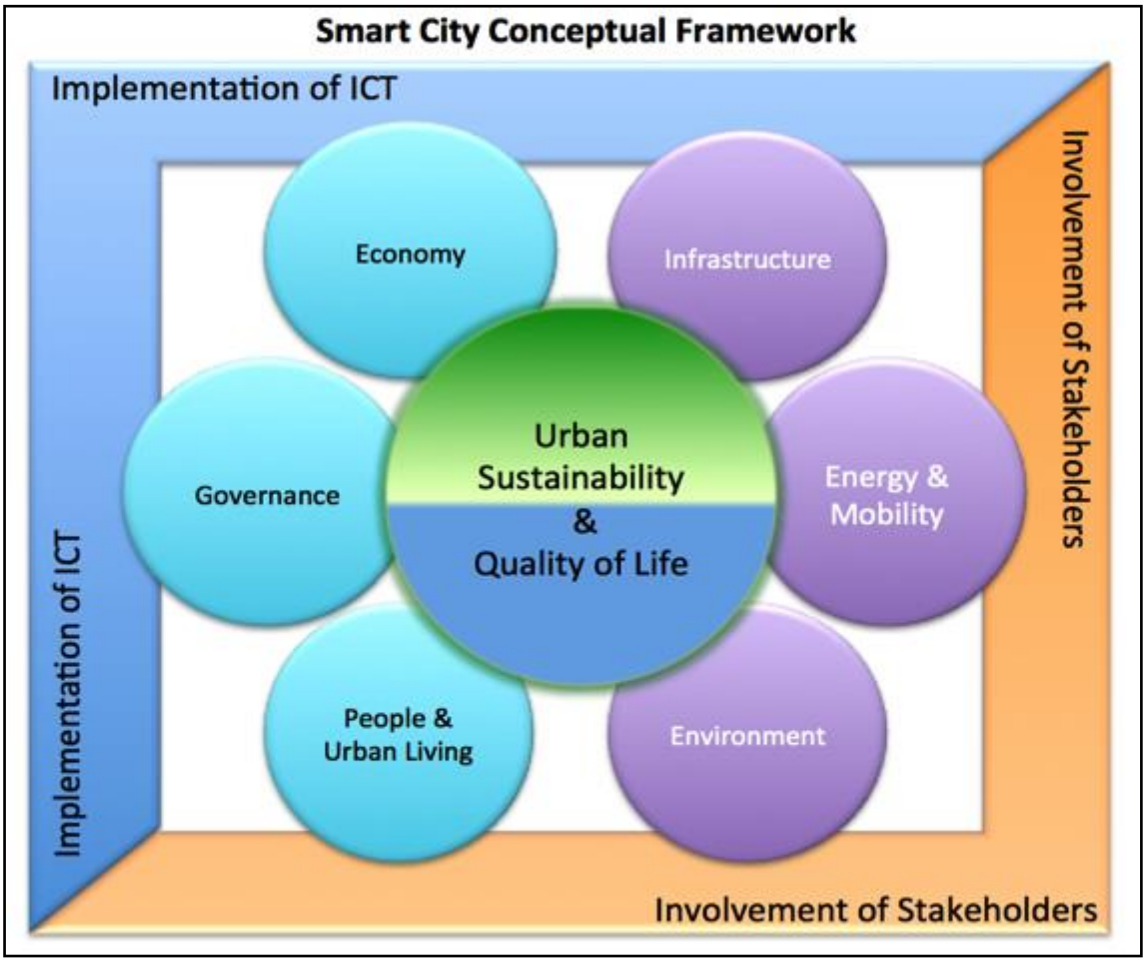

Figure 6-3 Conceptual framework for Smart City proposed by the author

6.3.2 Smart City Index (Indicator Selection)

Under this SC conceptual framework, a customized SC Index with six domains consisting of 18 aspects (themes) with a total of 36 corresponding indicators is proposed.

First, the indicator source pools are identified, from which the relevant indicators are chosen based on their relevance, data availability, suitability and ease of operation. Preference is given to the indicator pool with the most relevance and applicability. Two categories of indicator pools are identified, namely, international and regional. The international category index entails either a large scope of target groups or broad implementation potentials, such as SC indicators proposed by Lazaroiu & Roscia (2012), while the regional category normally narrows down the scope and implementation boundaries, and is applicable to particular region. Examples such as Giffinger et al. (2007a)'s SC European Index was tailored specifically for countries in the EU; and the Asian Green City Index developed by the Economist Intelligence Union (EIU) are used to evaluating megacities in Asia, and IGES, a national think tank of Japan, also proposed general sustainability indicators for Japan.

For the selection of indicators, I conducted workshop discussions with different stakeholder representatives in a conference sponsored by a local environmental NGO based in Kitakyushu City. Representatives from academia, local communities, industry, and the nonprofit sector were presented with the proposed SC concept, and asked what are the key aspects or topics that they are most concerned with under each category. And finally, I summarized and categorized the answers into 16 commonly expressed aspects or themes under the proposed 6 domains. A total of 36 indicators were selected (with an average of 6 indicators under each domain) for our SC index based on the proposed SC conceptual framework (refer to Table 6-1).

Two major factors were considered regarding the numbers of indicators to be included. One is manageability of indicators, and the other one is the evaluation method of AHP for the later weighting stage, due to pair-wise comparisons by the expert groups. Since it follows:

$$m = n(n-1)/2 \tag{1}$$

where m is the quantities for pair-wise comparison and n is the number of items for pair-wise comparison (in our case, indicator). It is suggested to keep to a number of 7 minus or plus 2, which is an acceptable range for expert groups survey (Geopel, 2013a).

Table 6-1 Modifed SC Index for Kitakyushu City

Dimensions	**Aspects (themes)**	**Indicator and measurement**
Governance	Transparency & Management	● Perception of transparency of bureaucracy ● Perception of fight against corruption ● Monitoring of environmental performance
	Civil participation	● City representatives per resident ● Ratio of female city representatives ● Public participation in environmental decision-making
Economy	Innovation	● Ratio local government budget that is allocated for environment ● R&D expenditure in % of GDP
	Sustainable development	● Use of electricity per GDP ● Use of water per GDP
	Labor & Capital	● Gross city product per capita ● Number of households below poverty line
People & Urban living	Human health	● Number of doctors per 1000 population ● Number of hospitals per 1000 population
	Institutional & Social capacity	● Number of environment staff in city government per 1000 population ● Ratio of industries in compliance with emission control regulations ● Ratio of vehicles compliant with emission control regulations ● Adult literacy rate
Infrastructure	Buildings	● Energy consumption of residential buildings

		● Energy-efficient building standards
	Land use	● Green space per capita
	Smart grid	● Accessibility of smart grid
Energy & Mobility	Renewable energy	● Share of renewable energy in total energy use
	Energy efficiency	● CO2 per capita from energy use
	Sustainable transportation	● Green mobility share ● E-vehicle in commercial vehicle shares
Environment	Air quality	● SO2 concentration ● TSP concentration
	Water availability	● Ratio of population with access to adequate and clean water ● Water renewable rate of the source
	Water quality	● Water quality (measured by BOD, COD contents etc.)
	Urban green	● Ratio of green area in the total land use
	Waste & Waste water	● Per capita waste generation ● Ratio of total municipal solid waste (MSW) collected & treated

Note: The descriptions of indcitors are modifed for accuracy and understandbility. The quantity of indicators of Environment domain is reduced to 6, for the later AHP analysis.

6.4 Weighting of Smart City Indicators (Using AHP)

The AHP method is applied for the weighting of the proposed Smart City Index by surveying expert opinions. These experts are chosen based on their fields of research and teaching topics, years of experience of working either in academia or on practical projects from our network. Paper-based questionnaires are designed and prepared to survey the available experts in person, and for the ones not immediately available, I sent out the spreadsheet survey by emails within the course of one month. I intended for a survey sample of 60 experts, with an average inputs of 10 experts' weighting for each domain (theme) of the proposed index. A total of 44 valid responses have been collected for later analysis and display of weighting result.

According to the AHP methodology (Saaty, 1980), a decision-making problem can be generalized into three levels: objectives or goals for level 1; criteria for level 2; and alternative for level 3, as demonstrated in Figure 6-4 and 6-5.

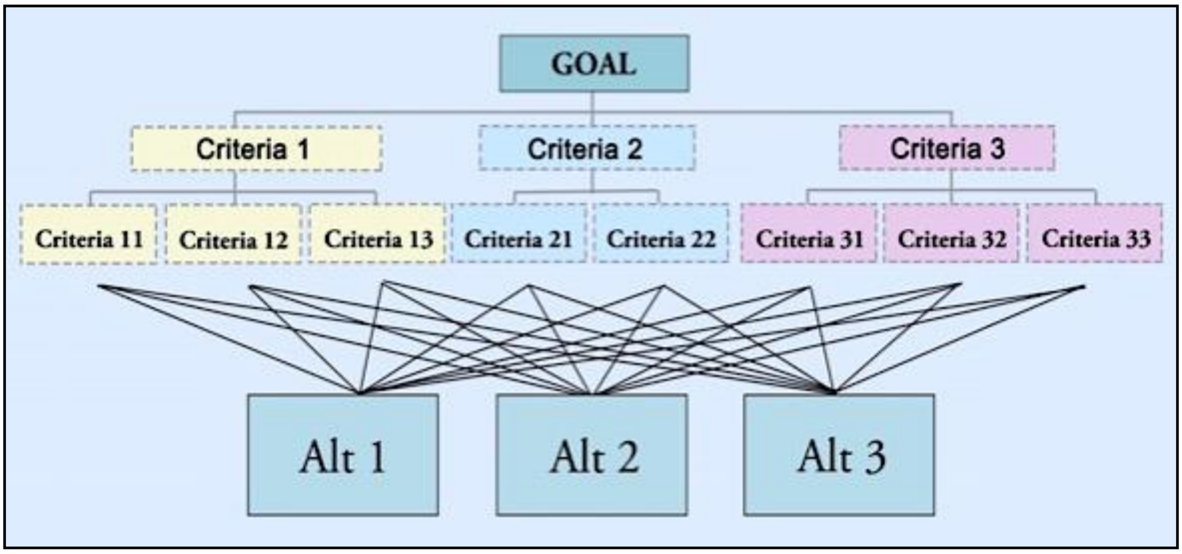

Figure 6-4 A General AHP Hierarchy Model

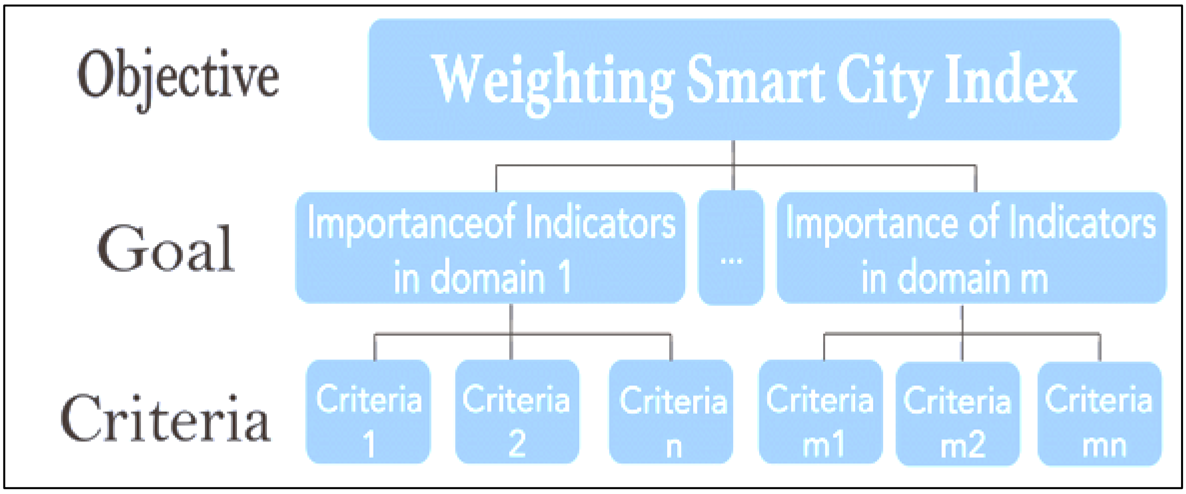

Figure 6-5 Customized AHP Hierarchy Structure

In this case, there is no alternative needed for selection purposes, only the evaluation for indicators. Therefore I customized the AHP hierarchy into a three-tier two level structure, with the overall objective being the “weighting of SC index”, and the goal is to evaluate the importance of the indicators under each domain, where the criteria under each goal are the individual indicators, as seen in Figure 6-5.

Next, I asked the respondents to evaluate each indicator (criterion) by pair-wise comparisons on a scale of importance from 1 to 9 under the goal of determining the importance of indicators. “1” denotes an equal significance, “3” denotes a slightly higher significance, “5” denotes a moderately higher significance, “7” denotes a considerably more significant level, and “9” denotes the highest possible significance. Table 6-2 illustrates the scale intensities.

Table 6-2 Explanations of AHP Scale Intensities in Survey

Scale Intensity	**Definition**	**Explanations**
1	Equally important	Both indicators are equally important for the objective
3	Slightly more (important)	One of the chosen indicaitor is slightly more imporant than the other in comparision for the objective
5	Moderateltly more (important)	One of the chosen indicaitor is moderately more imporant than the other in comparision for the objective
7	Consdierably more (important)	One of the chosen indicaitor is considerably more imporant than the other in comparision for the objective
9	Siginificantly more (important)	One of the chosen indicaitor is significantly more imporant than the other in comparision for the objective
2,4,6,8 can be used to express intermediate values for weighting calculations		

After collecting all the data, the data was fed into the AHP calculator developed by Goepel (2013a), wherein key parameters are calculated and key indicators are displayed for analysis. Several key indicators are included for SC index ranking purposes, such as the weights for indicators based on raw geometric mean method (RGMM), the consistency ratio (CR), the aggregated weights (AW) for indicators, and the group consensus ratio (GCR).

According to Goepel (2013a) the mathematical relationships and formulae used are as the followings:

A. Scales. Intensity x, with x = 1-9 (integer) are transferred to c using the following relations:

- 1-Liner c=x
- 2- Logarithmic c=$\log_2(x+1)$
- 3- Root square c=$\sqrt{x}$
- 4- Inverse liner c=9/(10-x)
- 5- Balanced c= w/(1-w); w={0.5, 0.55, 0.6, ... ,0.9}
- 6- Power c=x^2
- 7- Geometric c=2^{x-1}
- *c* is then used as element in the pair-wise comparison matrix

B. RGMM. Row Geometric Mean Method is used to calculate "Priorities" p_i in each input sheet. Pairwise NxN comparison is expressed as matrix $A=a_{ij}$

Where,

$$r_i = exp\left[\left[\frac{1}{n}\sum_{j=1}^{n}\ln\left(a_{ij}\right)^{1/n}\right]\right] \text{ = is calculated} \tag{3}$$

and

$$p_i = r_i / \sum_{i=1}^{N} r_i \text{ is normalized} \tag{4}$$

C. Inconsistencies. To find the most inconsistent comparison, they look for pair *i,j*

with

$$\max\left(\varepsilon_{ij} = a_{ij}\frac{P_j}{P_i}\right) \tag{5}$$

The consistency ratio (CR) is calculated using

$$CR = \frac{CI}{RI} \tag{6}$$

Using the Alonson/Lamata linear fit (Alonso & Lamata, 2006) resulting in CR:

$$CR = \frac{\lambda_{max} - N}{2.7699\,N - 4.3513 - N} \tag{7}$$

- where “CR” is the consistency ratio,
- “CI” is the Consistency Index,
- “RI” is the Random Index.
- “n” is the order of matrix.

The group consistence ratio is calculated based on the aggregation of individual judgments. The consolidated decision matrix C (selected participant “0”) combines all *k* participants’ inputs for the aggregated group results, using

$$C_{ij} = exp\,\frac{\sum_{k=1}^{N} w_k \ln a_{ij(k)}}{\sum_{k=1}^{N} w_k} \tag{8}$$

where “k” is the number of participants,

“a_{ij}” are the decision matrices elements,

“W_k” is the weight for participant’s weight for each indicator.

The aggregated weight for indicator is calculated based on the geometric mean of participants’ weight of the same indicator, the formula is as the follows:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} = \frac{x_1 + x_{2+\dots} x_n}{n} \tag{9}$$

where "$\bar{x}$" is the aggregated weight for an indicator,

"x_i" is the number of each individual RGMM of indicator,

"n" is the number of appearance of each individual indicator.

After the calculating the CR of each participant's survey result, the ones exceeding the CR threshold of 20% were then removed. Normally, CR within the range of 10% to 20% is deemed consistent for judgments (Goepel, 2013b).

6.5 Survey Results and Discussion

After conducting the AHP analysis of the collected participants' survey results, and removing the ones deemed not consistent enough for further analysis (CR>10%), the following results are then obtained (Table 6-3 to Table 6-8).

For the smart city "Governance" domain (refer to Table 6-3), the most important indicators are "Perception of transparency of bureaucracy" and "Monitoring environmental performances", both of which consist of an aggregated weight of 56.5% (32.3% + 24.2%). The least weighted indicator under this domain is "Female city representatives per (1000) residents", which takes 5.5% of the aggregated weights. The experts' opinions on this domain, however, researched a group consensus ratio of 67.7%, not the highest compared to other domains. This might be due to the rather qualitative nature of most indicators in this group, and the ambiguous nature of "governance" itself.

Table 6-3 Weighting for Smart City Governance

Smart City Governance (domain/theme)		
Indicators	Aggre. Weights	Ranking
Perception of transparency of bureaucracy	32.3%	1
Monitor its environmental performances	24.2%	2
Public participation in environmental decision-making	19.2%	3
Perception of fight against corruption	13.0%	4

City representatives per (1000) resident	6.4%	5
Female city representatives per (1000) resident	5.5%	6
Number of participant: 8	Group Consensus Ratio: 67.7%	

As is seen in Table 6-4, for the "Economy" domain of smart cities, the group consensus ratio is even lower than that of the previous "governance" section at 57.2%. It might appear to be counterintuitive why rather quantified indicators in the economic sector would have more disparities in consensus. Top two indicators are "R&D expenditure in % GDP " and "Use of electricity per GDP", making up 22.8% and 20.4% perceptively of aggregated weights. The least weighted indicator is "Households below poverty line" with 11.4%. This might due to the fact that most of the experts are currently working in a Japanese institute, a geographical setting where poverty is not an immediate concern. Additionally, each indicator received less volatile percentage in AW (11.4% to 22.8%), which suggests all these highly quantifiable indicators are valued on similar levels of prioritization.

Table 6-4 Weighting for Smart City Economy

Smart City Economy (domain/theme)		
Indicator (Criteria)	Aggre. Weights	Ranking
R&D expenditure in % of GDP	22.8%	1
Use of electricity per GDP	20.4%	2
% of budget of local government allocated for environment	19.6%	3
Gross city product per capita	13.5%	4
Use of water per GDP	13.3%	5
Household below poverty line	11.4%	6
Number of participant: 6	Group Consensus Ratio: 57.2%	

Regarding the “People & Urban Living” domain, a second highest group consensus rate of 74% is obtained, which indicates that it is easier to reach an agreement on the importance or certain aspects concerning people and urban living. As displayed in Table 6-5, the weights are highest for the indicators “Number of doctors per 1000 population” and “Adult literacy rate”. While the number of hospitals resembling the number of doctors per unit, it receives the least AW with 8.8%. This might be due to the similar nature of the two indicators, or it could reveal a certain belief that people such as doctors play more important roles than that of the physical infrastructure of hospitals. While medical personnel would contribute to the overall quality of living, the literacy rate would benefit the residents’ overall level of development, as common sense result.

Table 6-5 Weighting for Smart City People & Urban Living

Smart City People Urban Living (domain/theme)		
Indicator (Criteria)	Aggre. Weights	Ranking
Number of doctors per 1000 population	25.8%	1
Adult literacy rate	25.2%	2
% of industries complied with emission control regulations	17.0%	3
% of vehicles complied with emission control regulations	13.3%	4
Number of environmental staffs in city government per 1000 population	9.3%	5
Number of hospitals per 1000 population	8.8%	6
Number of participant: 6	Group Consensus Ratio: 74.0%	

There are only four indicators each under the “SC Infrastructure” and “SC Energy & Mobility” domains. This should have inevitably lead to more concentrated AW values for each indicator as common sense dictates. However, to our surprise, most experts have reached the consensus on weighting “Green spaces per capita” with 38.3% AW, which is much higher (almost 3 times) than that of the least weighted indicator “Energy-efficient building standards” (14.7% AW) in this group. And similar cases also manifest in the

SCE&M domain, where “Share of renewable energy in total energy use” and “CO2 per capita from energy use” takes up the majority in AW, 46.8% and 24.9% respectively. Whilst the least weighted indicators in both domains are “Accessibility to smart grid” and “E-vehicle in commercial vehicle shares” both with 14.1% AW.

This could be explained by the proposed SC conceptual framework, which unlike the ICT focused concept, pursues the overall urban sustainability as whole with ICT as one major instrument. It could also indicate the immature applications of ICTs for E-vehicles on a commercial scale, which causes less preference in weighting by the experts.

Table 6-6 Weighting for Smart City Infrasctructure

Smart City Infrastructure (domain/theme)		
Indicator (Criteria)	Aggre. Weights	Ranking
Green spaces per capita	38.3%	1
Accessibility of smart grid	26.3%	2
Energy consumption of residential buildings	20.7%	3
Energy-efficient building standards	14.7%	4
Number of participant: 6	Group Consensus Ratio: 68.0%	

Table 6-7 Weighting for Smart City Energy & Mobility

Smart City Energy & Mobility (domain/theme)		
Indicator (Criteria)	Aggre. Weights	Ranking
Share of renewable energy in total energy use	46.8%	1
CO2 per capita from energy use	24.9%	2
Green mobility share	14.1%	3
E-vehicle in commercial vehicle shares	14.1%	3
Number of participant: 8	Group Consensus Ratio: 79.1%	

In terms of the “SC Environment” domain, I originally proposed 10 indicators under the five themes within this domain. Given the consideration of comparison confinement, I combined them into 6 indicators after consulting with experts in the field. Two indicators, namely “percentage of population with access to adequate and clean water” and “Air quality (indicated by SO2, TSP)” gained better share of the AW totaling at 45.3% (25.5% + 19.4%). Other indicators regarding waste generation and treatment receive less AW within this domain.

These results also reflect the physical situation of Japan, where most of the surveyed people are located. Japan is known for rigorous efforts in environmental protection and good quality of water and air, particularly compared to other countries in Asia like China, India, and Indonesia. It is also observed that Japan has a well-established waste separation and collection system already in place for both waste generation and treatment. Thus, the lower AW on waste related indicators are understandable given the already solid solutions in place.

Table 6-8 Weighting for Smart City Environment

Smart City Environment (domain/theme)		
Indicator (Criteria)	Weights	Ranking
% of population with access to adequate and clean water	25.5%	1
Air quality (indicated by SO2, Total Suspended Particles)	19.4%	2
% of total wastewater treated or recycled	17.8%	3
Water quality (measured by BOD, COD contents etc.)	15.8%	4
Per capita waste generation	11.1%	5
% of total municipal solid waste (MSW) collected & treated	10.5%	6
Number of participant: 8	Group Consensus Ratio: 57.6%	

There are some limitations regarding this model. Firstly, SC initiatives as reflections of urban development policy should consider both policy makers' opinions and those of other key stakeholders'. In this section, I focused more on the academic interpretation of what constitutes a smart city by reviewing previous works. A more desirable approach is to refer also to what the decision-makers' consensus tells us, given their deciding role in real life implementation.

Regarding the selection of indicators, both of the quantity and quality of indicators matter in the composition of index. There is not yet any single "best method" that would meet all the needs or requirements or fit perfectly to different geo-social or geopolitical settings. Therefore, it is necessary to define manageable scopes and proper system boundaries under clear objectives and frameworks. What has been proposed as SC Index under its conceptual framework might not be compatible to the needs of other regions, sectors or industries. That is why localization and customization are needed for this work to be adaptable.

In terms of the weighting of indicators, I have received feedback from the surveyed experts that misinterpretations are likely to occur given the lack of specific case settings. Even though they were presented or instructed with the defined concepts and objectives of indicator weighting, respondents might perceive the indicators very differently based on their own background and experience. This is also a reflection of the trickiness in quantification based on subjective judgments, which is part of the reason why AHP was adopted for evaluation in this study.

6.6 Chapter Conclusion and Discussions

Under the current global trend seeing smart cities as the newest sustainable cities, despite its numerous interpretations, I have identified two schools of thought regarding its concept or framework. One is focusing on taking what the information era has to offer in the forms of ICTs to improve the quality of life; the other tends to embark on a broader scope to make cities become "smart" in various urban dimensions. I propose, based on the substantial literature reviewed, an encapsulating conceptual framework for smart city that contains dual goals, six major domains as development contents and two instruments for translating the concepts into reality.

As an important vehicle for assessing different aspects of smart cities, I have proposed a coupling SC Index (indicator system) with 36 indicators that measures the 16 aspects or themes under the proposed 6 domains of smart cities. The deployment of such an index would better facilitate and measure the realization of SC concept into reality with specific indicated qualities or quantities.

Furthermore, the AHP method is applied for the weighting of the proposed index, where priorities would manifest for each indicator as the results of quantitative evaluation of experts' opinions and judgments. The weighting would be insightful and useful in many occasions, such as proposing key performance indicators (KPIs), when only a handful of indicators are needed instead of the whole index. And what priorities would be given upon conflicts or interferences of similar indicators or some other cases where further preferences or selection are needed within the index.

On an equally important note, it is found that the adopted approach or methodology of this study can also be transformed into a more positive mechanism for customizing urban development policies for sustainable cities in general. Throughout this study many of the steps that have been taken, or the mathematical methods applied, can be flexibly adjusted to a particular setting. I have summarized them in the following approaches and steps:

- Define the scope and proposed framework for urban city package (could be eco- or low-carbon or smart city). This could be achieved by either having a thorough literature review or commissioned inputs under a suitable chosen framework.
- Develop an index or measurement indicator system based on proposed scopes and framework. First, to identify indicator source, then select indicators based on SMART (specific, measurable, assignable, realistic, time-related) principles or customer needs, and finally integrate them into index.

- Weight or evaluate the proposed indicators using AHP (or other methods for weighting). This can be found by identifying survey groups (experts or other stakeholders), and conducting surveys or questionnaires, which will be later used for AHP analysis.

Last but not least, I want to reiterate that it was never my intention to downplay the importance of the IT sector where big data and ITCs are gaining more momentum in transforming cities into smart cities, nor do I try to prove that this proposed concept or index could provide a “panacea” for all urban ills regarding smart city development. Instead, I try to offer my take regarding what an inclusive smart city would look like, what are the major features, and how to evaluate them. More importantly, this endeavor of developing smart cities should involve multiple stakeholders throughout the process based on the local settings and contexts.

7 CONCLUSIONS

7.1 Chapter Introduction

Human history is somehow a history of urbanization and globalization. Cities are the complex and dynamic systems where the exchanges of information, economic and social activities. With the speed of technology advancement and industrialization, development-led prosperity became a low-hanging fruit for the urbanized sphere, and contributed to the formation of more cities at even bigger scales. In the mean time, urban “illnesses” resulted from the disruptions of ecological system and ambient environment, climate changes, energy and resource crisis, various millennium challenges have devastated human societies on planet earth. A paradigm shift or change is desperately craved and needed from the long-term perspective. Starting from the early UK’s urban model of “Garden Cities” in late 1890s, continuous trends of pursuing in the pursuit of sustainable cities, such as “Eco-cities”, “Low-carbon Cities” and “Smart Cities” have been seen on a global scale, with incremental momentum in the past decades.

Despite the multitudinous sustainable city projects developed or being undertaken worldwide, there are still gaps in comprehending or understanding the constitutions of these sustainable urban development models. Moreover, the vacancies in systematic approaches or methods for standardizing and evaluating these sustainable movements or urban trends have made developing such projects within urban boundaries quite ambiguous and imprecise in terms of policy implementation and regional replicability. This thesis attempted to answer the overarching questions of how to understand and how to evaluate these sustainable cities of major sustainable urban trends in an East Asia setting, with selected case studies from two leading powers of China and Japan.

Amongst a number of urban categories or development models, three major sustainable urban trends were identified and selected for this thesis, namely, “eco-cities”, “low-carbon cities” and “smart cities” based on both academic and country policy relevance. The first identified trend of “eco-cities” is studied in a Chinese context with a comparison of Japan’s case, in terms of the concept, definition and indicator systems. The second trend of “low-carbon cities” also focused on China’s situation with two case studies from Japan and Germany for comparison and reference. The third urban global trend of smart cities was framed within the Japanese background for in-depth analysis with case study of the City of Kitakyushu. And an integrated approach from concept understanding to index for evaluation and final weighting of indicators was distilled that can be generalized and applied to sustainable cities in general.

7.2 Research Findings and Contributions

7.2.1 Research Findings

An “Eco-city” can be regarded as the result of the globally reached consensus regarding paradigm shift towards sustainability in urban development. The focus, despite of its vagueness in terms and multifold interpretations, is to rebalance the economic development with ecological and environmental system and solve the “urban illnesses” in our society. Protecting the environmental conditions manifested as one of the core principles of this global trend for sustainable urbanization.

China’s efforts of pursuing harmonious development between human and nature can be traced back to the oriental concept of “Shanshui City”. From analyzing the Chinese Eco-city development, it is observed that China’s Eco-cities aim to promote more sustainable growth regarding economic, environmental, and social aspects as national policies. The focus has begun to weigh in more towards the environment instead of economic development.

However, when compared to regional leading country of Japan, there are a number of categories out performed by the Japanese case in terms of efficiency and performance of energy sector, waste treatment and recycling sector, and pollution emission in particular. This indicates the challenges faced by such a geographically vast country like China with diverse local development levels and having one set of top-down national standards. More importantly, further improving and updating of the relevant guiding policies with more explicitly defined methods is definitely needed.

Low-carbon cities bring forth a more clear and measurable standard or principle "decarbonization" or "low-carbonization" for urban development. This global trend arose as a specific reaction towards the common foe of "climate change" and "global warming" faced by all human kind. And the development of the Kyoto Protocol in 1997 has globalized this "new norm" in urban sustainable developments.

China is currently the world's largest gross GHG emitting country, and Japan ranks the third in GHG emission after China and India in Asia (in 2013). To reduce GHG emissions, they have proposed and developed common but differentiate strategies. China focuses more on "CO2 emission reduction and adaptation plans" with strong government intervention and civil participation. While Japan's focus is on development of "low-carbon society" and "climate change resilience" that facilitated by sound science and technology applications.

Since late 1990s, many noticeable adjustments can be observed in China's urban development trajectory towards sustainability. The quick adaptation of low-carbonization as a national development objective reflects the international response to global warming and climate change. Additionally, a shift from top-down to bottom-up urban policy development approach is seen from the previous Garden City and Eco-city to Low-carbon City in China, due to its gigantic geographic coverage and local geopolitical characteristics.

However, there is still a lack of explicitness in definition or even overlapping in different urban development models. Sometimes, the low-carbon title or the political incentives behind these "environmentally-friendly city" designations outweigh the actual commitment in reducing carbon in the city developments. Also, there are many international practices that can offer excellent lessons or references to China's low-carbon city development.

The "smart cities" trend can be regarded as the most recent urban development model in the information era. With the rapid advancement of information and digitalization, ITCs such as big data and sensors, innovative means for gathering and processing information and data are being developed for city development and management, also known as "big-data based smart urban management".

As the information and digitalization process accelerates in China, smart city development has been incorporated into the national development strategies that features in “the Internet plus extended industries” mode and ICT infrastructure development. While Japan’s digitalization levels are higher than China, therefore Japanese smart city development has it own characters of goals, implementations and evaluation.

After reviewing and analyzing the current smart city concepts and frameworks, I conclude and propose a version conceptual framework for smart city as: “A city pursuing the twofold goal of improving quality of life while simultaneously realizing urban sustainability. The framework’s major contents include both hard and soft urban domains such as “Governance”, “People & Urban Living”, “Economy”, “Infrastructure”, “Energy & Mobility”, and “Environment”. The active involvement of stakeholders and implementation of information and communication technologies (ICTs) are the major instruments for implementation.”

It was then applied in a case study of Kitakyushu City of Japan using a customized Smart City Index consisting of 6 domains, 18 aspects with 36 measuring indicators. This was followed by an expert opinion survey to support an AHP method for indicator weighting. This additional step for indicator development proved to be very informative and useful in the selection of key performance indicators (KPIs) from numerous inventories and the prioritization of indicators for better or effective policy implementation.

In particular, the introduction of AHP as an indicator weighting mechanism or tool provides more rationality in the integration of indicator weights into the proposed index. Despite of certain limitations, the application of AHP in this thesis for expert survey provides some new insights of how “sustainable city” indicators could be further evaluated.

7.2.2 Research Contributions

The most important contribution of this thesis, besides the case studies and the existing body of literature regarding these urban development trends, is the conceptualized methodology (or methodological approach) from conceptual framework composition, to index or indicators selection and index development, to the final indicator weighting that has been distilled from these studies. It can be summarized as follows:

- First, defining the scopes and proposing a framework for urban/city development (i.e. eco-city, low-carbon city, smart city). This is achieved by having reliable sources of policy inputs such as those from the key decision makers or stakeholders, or from highly regarded literature.
- Second, developing an index or indicator system for measurement and evaluation based on the proposed framework. This required us firstly to identify indicator sources under specific goals or objectives, then to conduct a fine selection of supporting indicators based on SMART principles, and finally to integrate them into a complete index.
- Third, weighting or evaluating the proposed indicators using the Analytical Hierarchy Process (or other mathematical methods such as weighted preferences or Z score etc.). This can be realized by identifying expert groups for survey (could also be those people who are have expert knowledge of the intended areas) by questionnaires or workshops. And finally a weight is assigned to each individual indicator.

As an original contribution to the existing approaches for understanding and evaluating urban development, this integrated methodology will contribute to the pragmatic action that are flexible and adjustable with local context for policy and decision makers, urban managers, and key stakeholders from academia and industries.

7.3 Limitations

Urban sustainable development is a topic too broad to tackle or explain in a single dissertation. It can also be a simple term such as “development, which meets the needs of the present without compromising the ability of future generations to meet their own needs.”

Therefore it is vital to consider and study it within proper local frames or boundaries. Due to the scope and research encompassed within this dissertation, there are several limitations regarding certain methods or process designs incorporated into the studies.

For the quantitative indicator comparisons of China’s eco-cities with the case study from Japan, the baseline scenario was chosen from MHURD’s standards. As is pointed out repeatedly throughout this thesis, various geo-political and geo-cultural situations can lead to different standards upheld and adopted in different regions or places. Not all the indicators are directly comparable, nor were the all the relevant data available. Even though Suzhou city is a very representative well-developed city in China, it can only represent Chinese cities with limited geo-social features.

For the low-carbon city research, a qualitative approach was taken to derive in-depth knowledge and references for improving China’s low-carbon urban policies through field studies and in-depth interviews with key stakeholders in the selected cities of Japan and Germany. However, although the lessons learned from the two cases may offer some good references, they need to be presented to the key decision or policy makers in China before any concrete suggestions could be translated into reality. It would be helpful to have also selected two corresponding Chinese cities where the policies recommendations for low-carbonization could be compared, implemented and tested.

In regards to the smart city research, not like many studies where ICTs are given the most weight in consideration for either conceptualization or index development, I have considered it as a means to realize the urban development goals of improving life quality and pursing sustainability. But it is not my intention to claim that these ICTs like big data, sensors etc. are less important. On the contrary, the very core nature of smart cities are to utilize them for better urban goal or policy implementations. Thus the proposed smart city conceptual framework or index could lead to some disagreement due to the lack of ICT related contents in proportion. On the other hand, I also rigorously reiterate that locality needs to be integrated from the beginning in the policy design for smart cities.

The last search package of the integrated approach has improved upon the above-mentioned limitations of the smart city study to certain extent. This integrated approach consists of a three-step mechanism with customizable sub-steps. But it is only based on one local case study of Kitakyushu City in Japan as of this time. For the expert option surveys, there are only 60 experts invited for this study, thus the sample size might not be that reliable. This also resulted from the adopted survey analytical tool of AHP, which has number limits in calculating the item evaluating inputs. For the questionnaire itself, some of feedback may be less accurate due to the unfamiliarity with the scale selections for some people. Improvement is definitely needed for such clarification in the instruction part of future surveys.

This integrated approach is summarized and distilled mainly from the three case studies enlisted in the thesis, therefore it might be confounding when applied to another model of sustainable urban or another different geographical setting. That is also the reason this approach needs to be flexible and customizable. And other major regret is that one of the main players of East Asia – South Korea was not included in this thesis, mainly due to the research scope and data availability. It may be very informative to see the smart city developing in Korea, given the high development in ICT infrastructures.

7.4 Future Research Perspectives

Ever since the industrial revolution, the momentum of human urbanization has continuously increased. A number of urban development trends have occurred along the timeline of human advancement during this time period. From Garden City and Green City, to Eco-City Low-carbon City, and to the current Smart City, all of them attempt to restore a balance between nature and the human sphere, between economic development and sustainability. The focus of each urban model differs, and there is not any proven “best” means or strategy that could meet the needs of all the parties involved. Under such a predicament, one effective tactic is to determine the most suitable way instead of the best way for preserving our common future in this urbanized era.

I have investigated several problems under the three major urban mega-trends in the recent decades, but there is more to be done. One topic that would be particularly interesting and worth further research, is to apply this proposed integrated approach to localization in different countries and regions. Only through application and feedback will this mechanism demonstrate its true value due to its high flexibility and customizability. Another topic that could be further explored is the up scaling of the proposed SC index for measuring smart city performance in Japan. There are also several issues that could be further researched regarding the eco-/low-carbon cities in China, in terms of performance evaluation and policy recommendations with specific case study cities.

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APPENDIX

Table A 1 Smart City Index Weighting Inputs Breakdown

SC Governance	**P 1**	**P 2**	**P 3**	**P 4**	**P 5**	**P 6**	**P 7**	**P 8**	**AW**	**Rankings**
Perception of transparency of bureaucracy	7.2%	7.0%	49.0%	44.0%	17.0%	52.0%	45.0%	37.0%	**32.3%**	**1**
Perception of fight against corruption	13.6%	12.0%	10.0%	21.0%	6.0%	4.0%	22.0%	15.0%	**13.0%**	**4**
Monitoring environmental performance	38.2%	39.0%	18.0%	22.0%	48.0%	17.0%	3.0%	8.0%	**24.2%**	**2**
City representatives per (1000) residents	3.5%	4.0%	4.0%	7.0%	11.0%	16.0%	3.0%	3.0%	**6.4%**	**5**
Female city representatives per (1000) residents	6.1%	7.0%	4.0%	3.0%	8.0%	4.0%	4.0%	8.0%	**5.5%**	**6**
Public participation in environmental decision-making	31.4%	32.0%	15.0%	3.0%	11.0%	8.0%	24.0%	29.0%	**19.2%**	**3**
GCR **67.70%** CR	11.7%	9.0%	9.0%	6.0%	9.0%	8.0%	10.0%	9.0%		
SC Economy	**P 1**	**P 2**	**P 3**	**P 4**	**P 5**	**P 6**	**P 7**	**P 8**	**AW**	**Rankings**
% of budget of local government allocated for environment	5.0%	24.0%	27.0%	5.0%	28.0%	45.0%	12.0%	11.0%	**19.6%**	**3**

R&D expenditure in % of GDP	12.0%	42.0%	47.0%	21.0%	2.0%	19.0%	19.0%	12.0%	**21.8%**	**1**
Use of electricity per GDP	16.0%	8.0%	7.0%	13.0%	42.0%	16.0%	23.0%	38.0%	**20.4%**	**2**
Use of water per GDP	16.0%	10.0%	6.0%	28.0%	4.0%	12.0%	10.0%	20.0%	**13.3%**	**5**
Gross city product per capita	27.0%	10.0%	9.0%	21.0%	17.0%	5.0%	13.0%	6.0%	**13.5%**	**4**
Households below poverty line	23.0%	6.0%	4.0%	11.0%	7.0%	3.0%	23.0%	14.0%	**11.4%**	**6**
GCR **57.20%** CR	4.0%	8.0%	7.0%	8.0%	10.0%	10.0%	10.0%	9.0%		
SC People &Urban Living	**P 1**	**P 2**	**P 3**	**P 4**	**P 5**	**P 6**	**P 7**	**P 8**	**AW**	**Rankings**
Number of doctors per 1000 population	38.0%	36.0%	6.0%	6.0%	50.0%	19.0%			**25.8%**	**1**
Number of hospitals per 1000 population	5.0%	17.0%	4.0%	6.0%	18.0%	3.0%			**8.8%**	**6**
Number of environmental staffs in city government per 1000 population	11.0%	9.0%	19.0%	5.0%	2.0%	10.0%			**9.3%**	**5**
% of industries compliant with emission control regulations	9.0%	4.0%	32.0%	38.0%	9.0%	10.0%			**17.0%**	**3**
% of vehicles compliant with emission control regulations	11.0%	7.0%	29.0%	17.0%	6.0%	10.0%			**13.3%**	**4**

Adult literacy rate			26.0%	28.0%	10.0%	27.0%	15.0%	47.0%			**25.5%**	**2**
GCR	**74.00%**	CR	6.0%	10.0%	8.0%	10.0%	10.0%	10.0%				
SC Infrastructure			**P 1**	**P 2**	**P 3**	**P 4**	**P 5**	**P 6**	**P 7**	**P 8**	**AW**	**Rankings**
Energy consumption of residential buildings			22.0%	17.0%	11.0%	7.0%	11.0%	56.0%			**20.7%**	**3**
Energy-efficient building standards			14.0%	16.0%	29.0%	17.0%	9.0%	3.0%			**14.7%**	**4**
Green spaces per capita			59.0%	4.0%	6.0%	64.0%	70.0%	27.0%			**38.3%**	**1**
Accessibility of smart grid			5.0%	64.0%	53.0%	12.0%	10.0%	14.0%			**26.3%**	**2**
GCR	**68.00%**	CR	9.0%	10.0%	9.0%	7.0%	10.0%	10.0%				
SC Energy & Mobility			**P 1**	**P 2**	**P 3**	**P 4**	**P 5**	**P 6**	**P 7**	**P 8**	**AW**	**Rankings**
Share of renewable energy in total energy use			41.0%	69.0%	28.0%	30.0%	50.0%	59.0%	41.0%	56.0%	**46.8%**	**1**
CO2 per capita from energy use			46.0%	10.0%	48.0%	12.0%	6.0%	25.0%	21.0%	31.0%	**24.9%**	**2**

Green mobility share			6.0%	7.0%	12.0%	35.0%	22.0%	12.0%	15.0%	4.0%	**14.1%**	**3**
E-vehicle in commercial vehicle shares			6.0%	15.0%	12.0%	23.0%	22.0%	4.0%	23.0%	8.0%	**14.1%**	**3**
GCR	**79.10%**	CR	1.0%	9.0%	7.0%	8.0%	6.0%	9.0%	8.0%	10.0%		
SC Environment			**P 1**	**P 2**	**P 3**	**P 4**	**P 5**	**P 6**	**P 7**	**P 8**	**AW**	**Rankings**
Air quality (indicated by SO2, Total Suspended Particles etc.)			11.0%	4.0%	31.0%	44.0%	3.0%	13.0%	19.0%	30.0%	**19.4%**	**2**
% of population with access to adequate and clean water			5.0%	3.0%	4.0%	21.0%	37.0%	51.0%	48.0%	35.0%	**25.5%**	**1**
Water quality (measured by BOD, COD contents etc.)			11.0%	8.0%	23.0%	22.0%	16.0%	7.0%	19.0%	20.0%	**15.8%**	**4**
Per capita waste generation			42.0%	15.0%	9.0%	7.0%	4.0%	4.0%	3.0%	5.0%	**11.1%**	**5**
% of total municipal solid waste (MSW) collected & treated			21.0%	22.0%	9.0%	3.0%	6.0%	13.0%	5.0%	5.0%	**10.5%**	**6**
% of total wastewater treated or recycled			10.0%	48.0%	24.0%	3.0%	34.0%	13.0%	5.0%	5.0%	**17.8%**	**3**
GCR	**57.60%**	CR	9.0%	10.0%	8.0%	6.0%	10.0%	6.0%	9.0%	8.0%		

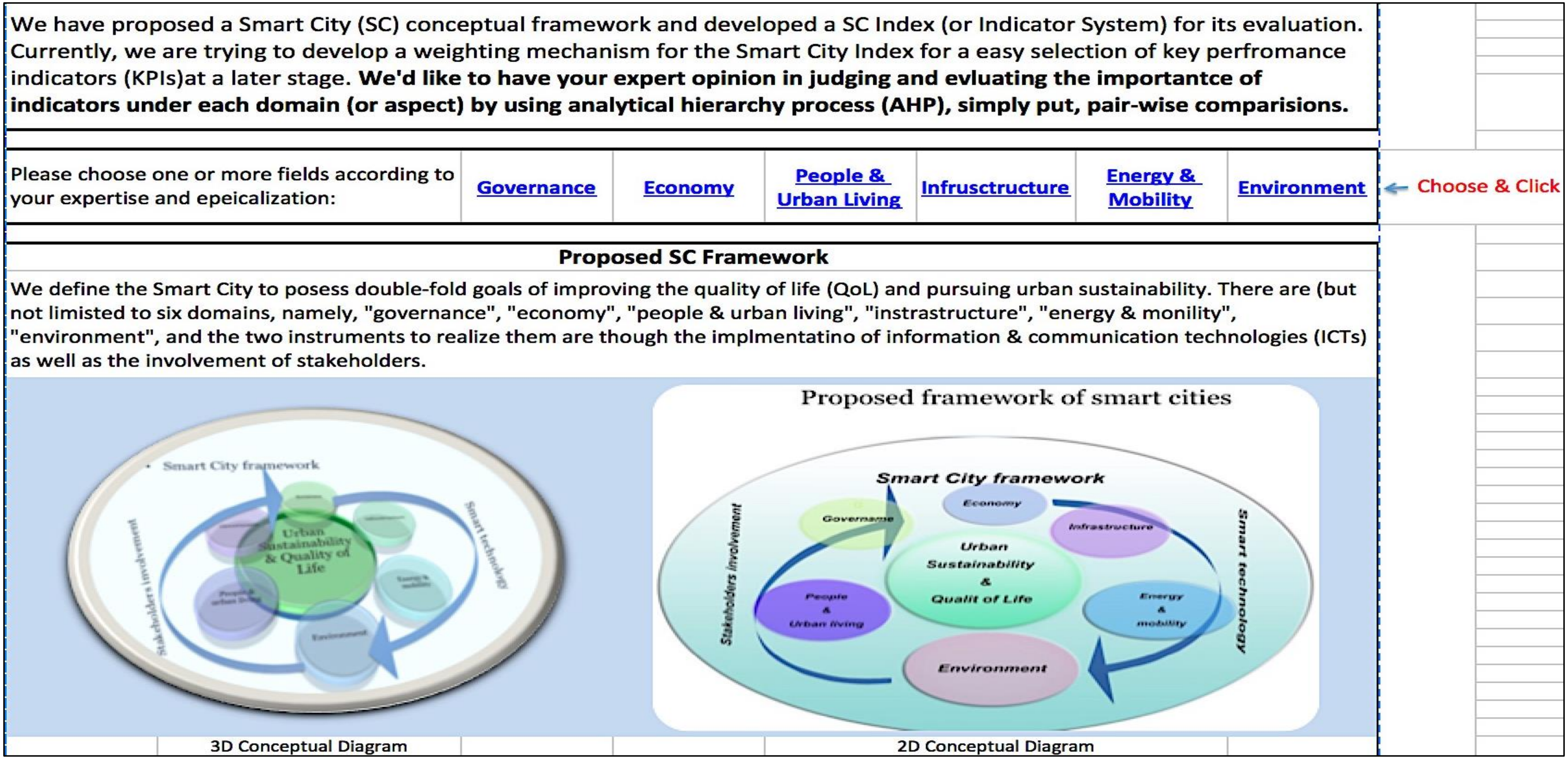
Note: “P” stands for “Participant”

“GCR” stands for “Group Consensus Rate”

“CR” stands for “Consistent Ratio”

“AW” stands for “Aggregated Weight”

Table A 2 Expert Survey Questionnaires



We have proposed a Smart City (SC) conceptual framework and developed a SC Index (or Indicator System) for its evaluation. Currently, we are trying to develop a weighting mechanism for the Smart City Index for a easy selection of key perfromance indicators (KPIs)at a later stage. **We'd like to have your expert opinion in judging and evluating the importantce of indicators under each domain (or aspect) by using analytical hierarchy process (AHP), simply put, pair-wise comparisions.**

Please choose one or more fields according to your expertise and epeicalization:	**Governance**	**Economy**	**People & Urban Living**	**Infrusctructure**	**Energy & Mobility**	**Environment**	← Choose & Click

Proposed SC Framework

We define the Smart City to posess double-fold goals of improving the quality of life (QoL) and pursuing urban sustainability. There are (but not limisted to six domains, namely, "governance", "economy", "people & urban living", "instrastructure", "energy & monility", "environment", and the two instruments to realize them are though the implmentatino of information & communication technologies (ICTs) as well as the involvement of stakeholders.

3D Conceptual Diagram

2D Conceptual Diagram

Your Inputs Below

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Which indicator do you think is **more Important** for **measuring a City's Smartness** in the aspect of "**Governance**"? (Choose one at each row)

	Indicators (A)				VS	Indicators (B)			
1	**Transparency of bureaucracy**				Vs	**Fight against corruption**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
2	**Transparency of bureaucracy**				Vs	**Monitor its environmental performances**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
3	**Transparency of bureaucracy**				Vs	**City representatives per (1000) resident**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
4	**Transparency of bureaucracy**				Vs	**Female city representatives per (1000) resident**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
5	**Transparency of bureaucracy**				Vs	**Public participation in environmental decision-making**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
6	**Fight against corruption**				Vs	**Monitor its environmental performances**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
7	**Fight against corruption**				Vs	**City representatives per (1000) resident**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
8	**Fight against corruption**				Vs	**Female city representatives per (1000) resident**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
9	**Fight against corruption**				Vs	**Public participation in environmental decision-making**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
10	**Monitor its environmental performances**				Vs	**City representatives per (1000) resident**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
11	**Monitor its environmental performances**				Vs	**Female city representatives per (1000) resident**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
12	**Monitor its environmental performances**				Vs	**Public participation in environmental decision-making**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
13	**City representatives per (1000) resident**				Vs	**Female city representatives per (1000) resident**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
14	**City representatives per (1000) resident**				Vs	**Public participation in environmental decision-making**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
15	**Female city representatives per (1000) resident**				Vs	**Public participation in environmental decision-making**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9

Please Leave your comments, if there is any

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Your Inputs Below

Which indicator do you think is **more Important** for **measuring a City's Smartness** in the aspect of "**Economy**"? (Choose one at each row)

	Indicators (A)				VS	Indicators (B)			
1	**% of budget of local government allocated for environment**				Vs	**R&D expenditure in % of GDP**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
2	**% of budget of local government allocated for environment**				Vs	**Use of electricity per GDP**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
3	**% of budget of local government allocated for environment**				Vs	**Use of water per GDP**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
4	**% of budget of local government allocated for environment**				Vs	**Gross city product per capita**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
5	**% of budget of local government allocated for environment**				Vs	**Household below poverty line**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
6	**R&D expenditure in % of GDP**				Vs	**Use of electricity per GDP**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
7	**R&D expenditure in % of GDP**				Vs	**Use of water per GDP**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
8	**R&D expenditure in % of GDP**				Vs	**Gross city product per capita**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
9	**R&D expenditure in % of GDP**				Vs	**Household below poverty line**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
#	**Use of electricity per GDP**				Vs	**Use of water per GDP**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
#	**Use of electricity per GDP**				Vs	**Gross city product per capita**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
#	**Use of electricity per GDP**				Vs	**Household below poverty line**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
#	**Gross city product per capita**				Vs	**Gross city product per capita**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
#	**Gross city product per capita**				Vs	**Household below poverty line**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
#	**Household below poverty line**				Vs	**Household below poverty line**			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9

Please Leave your comments, if there is any

Your Inputs Below

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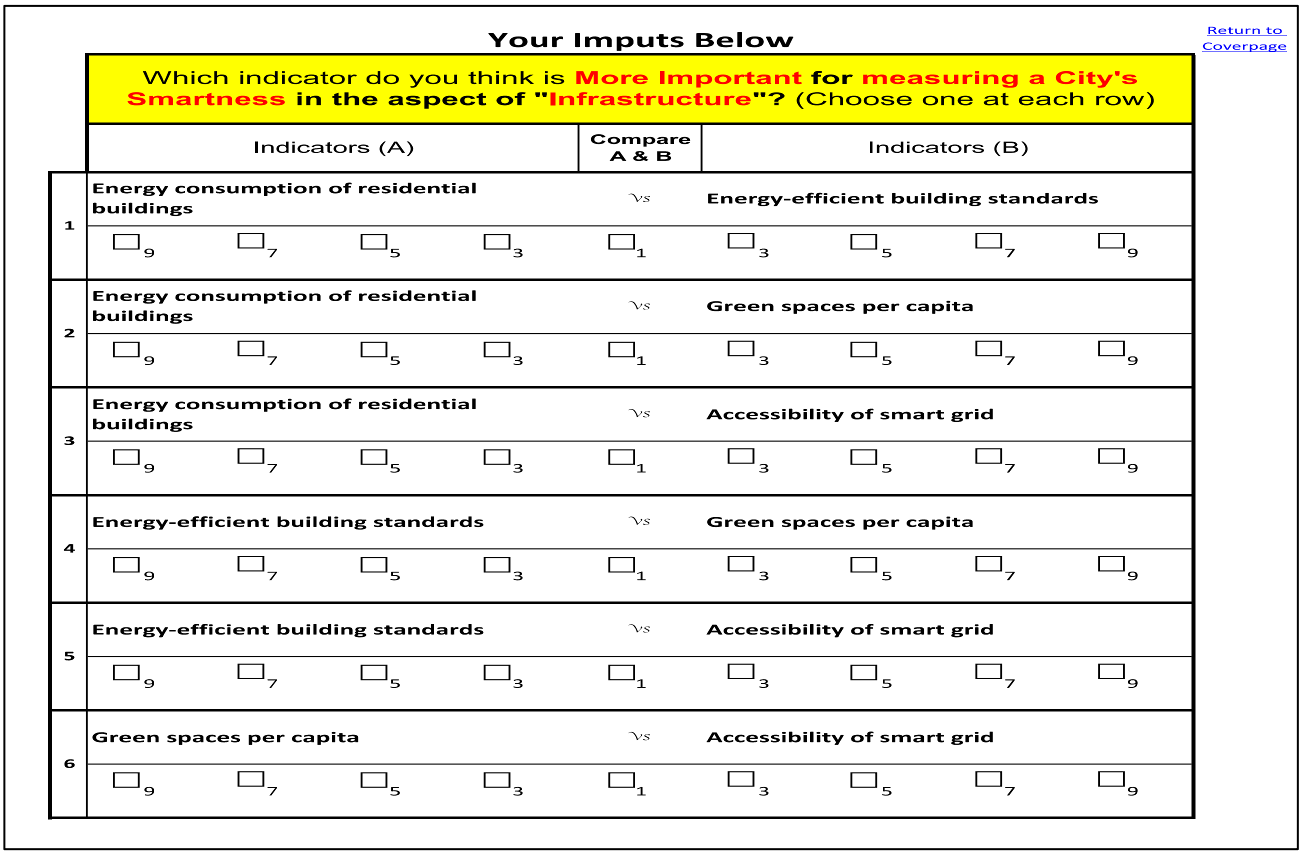
Which indicator do you think is **more Important** for **measuring a City's Smartness** in the aspect of "**People & Urban Living**"? (Choose one at each row)

	Indicators (A)	VS	Indicators (B)
1	**Number of doctors per 1000 population**	Vs	**Number of hospitals per 1000 population**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
2	**Number of doctors per 1000 population**	Vs	**Number of environmental staffs in city government per**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
3	**Number of doctors per 1000 population**	Vs	**% of industries complied with emission control regulations**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
4	**Number of doctors per 1000 population**	Vs	**% of vehicles complied with emission control regulations**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
5	**Number of doctors per 1000 population**	Vs	**Adult literacy rate**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
6	**Number of hospitals per 1000 population**	Vs	**Number of environmental staffs in city government per**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
7	**Number of hospitals per 1000 population**	Vs	**% of industries complied with emission control regulations**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
8	**Number of hospitals per 1000 population**	Vs	**% of vehicles complied with emission control regulations**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
9	**Number of hospitals per 1000 population**	Vs	**Adult literacy rate**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
10	**Number of environmental staffs in city government per**	Vs	**% of industries complied with emission control regulations**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
11	**Number of environmental staffs in city government per**	Vs	**% of vehicles complied with emission control regulations**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
12	**Number of environmental staffs in city government per**	Vs	**Adult literacy rate**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
13	**% of industries complied with emission control regulations**	Vs	**% of vehicles complied with emission control regulations**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
14	**% of industries complied with emission control regulations**	Vs	**Adult literacy rate**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
15	**% of vehicles complied with emission control regulations**	Vs	**Adult literacy rate**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9

Please Leave your comments, if there is any



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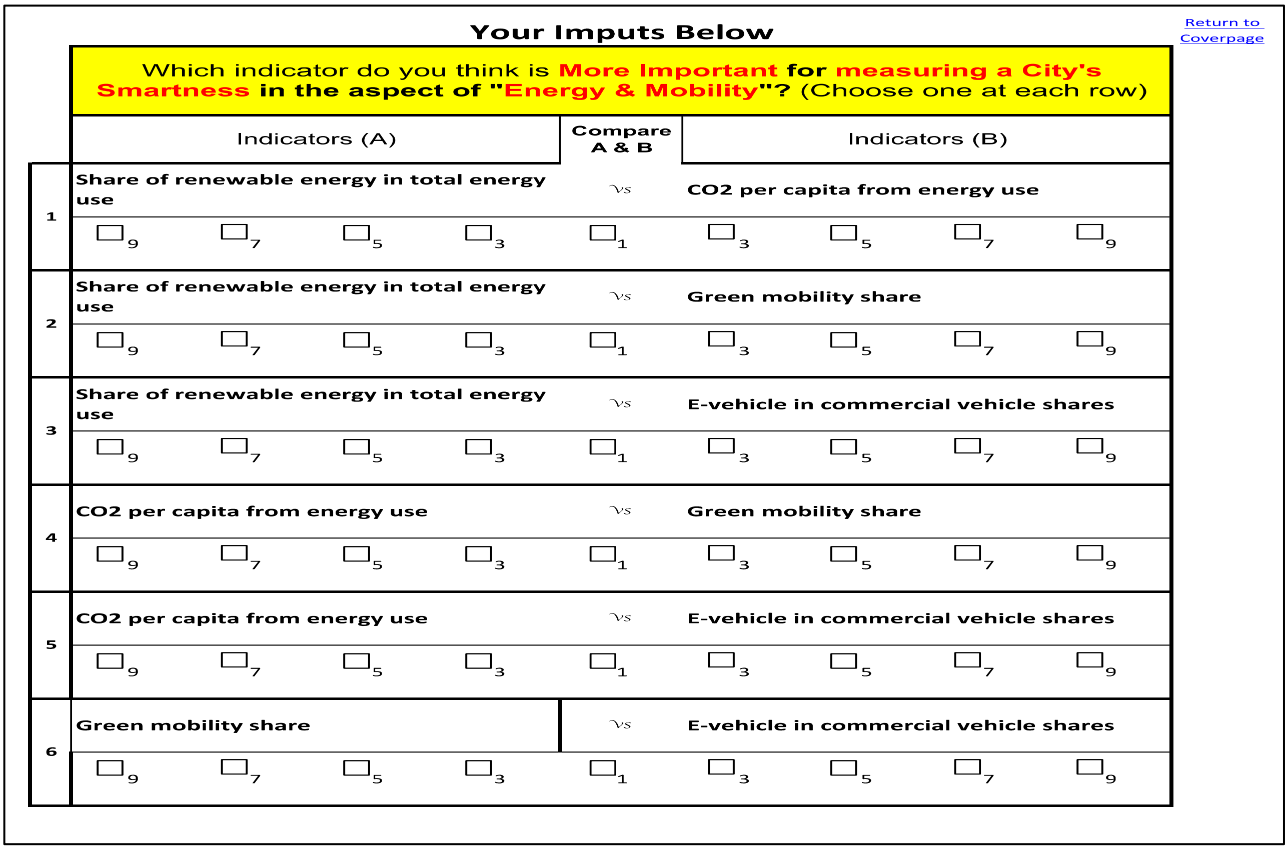
Your Imputs Below

Which indicator do you think is **More Important for measuring a City's Smartness in the aspect of "Infrastructure"?** (Choose one at each row)

	Indicators (A)	Compare A & B	Indicators (B)
1	**Energy consumption of residential buildings**	Vs	**Energy-efficient building standards**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
2	**Energy consumption of residential buildings**	Vs	**Green spaces per capita**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
3	**Energy consumption of residential buildings**	Vs	**Accessibility of smart grid**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
4	**Energy-efficient building standards**	Vs	**Green spaces per capita**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
5	**Energy-efficient building standards**	Vs	**Accessibility of smart grid**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
6	**Green spaces per capita**	Vs	**Accessibility of smart grid**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9



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Your Imputs Below

Which indicator do you think is **More Important for measuring a City's Smartness in the aspect of "Energy & Mobility"?** (Choose one at each row)

	Indicators (A)	Compare A & B	Indicators (B)
1	**Share of renewable energy in total energy use**	Vs	**CO2 per capita from energy use**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
2	**Share of renewable energy in total energy use**	Vs	**Green mobility share**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
3	**Share of renewable energy in total energy use**	Vs	**E-vehicle in commercial vehicle shares**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
4	**CO2 per capita from energy use**	Vs	**Green mobility share**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
5	**CO2 per capita from energy use**	Vs	**E-vehicle in commercial vehicle shares**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
6	**Green mobility share**	Vs	**E-vehicle in commercial vehicle shares**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9

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Your Inputs Below

Which indicator do you think is **more Important** for **measuring a City's Smartness** in the aspect of "**Environment**"? (Choose one at each row)

	Indicators (A)	VS	Indicators (B)
1	**Air quality (indivated by SO2, Total Suspended Particles etc.)**	Vs	**% of population with access to adequate and clean water**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
2	**Air quality (indivated by SO2, Total Suspended Particles etc.)**	Vs	**Water quality (measured by BOD, COD contents etc.)**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
3	**Air quality (indivated by SO2, Total Suspended Particles etc.)**	Vs	**Per capital waste generation**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
4	**Air quality (indivated by SO2, Total Suspended Particles etc.)**	Vs	**% of total municipal solid waste (MSW) collected & treated**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
5	**Air quality (indivated by SO2, Total Suspended Particles etc.)**	Vs	**% of total waste water treated or recycled**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
6	**% of population with access to adequate and clean water**	Vs	**Water quality (measured by BOD, COD contents etc.)**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
7	**% of population with access to adequate and clean water**	Vs	**Per capital waste generation**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
8	**% of population with access to adequate and clean water**	Vs	**% of total municipal solid waste (MSW) collected & treated**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
9	**% of population with access to adequate and clean water**	Vs	**% of total waste water treated or recycled**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
10	**Water quality (measured by BOD, COD contents etc.)**	Vs	**Per capital waste generation**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
11	**Water quality (measured by BOD, COD contents etc.)**	Vs	**% of total municipal solid waste (MSW) collected & treated**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
12	**Water quality (measured by BOD, COD contents etc.)**	Vs	**% of total waste water treated or recycled**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
13	**Per capital waste generation**	Vs	**% of total municipal solid waste (MSW) collected & treated**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
14	**Per capital waste generation**	Vs	**% of total waste water treated or recycled**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9
15	**% of total municipal solid waste (MSW) collected & treated**	Vs	**% of total waste water treated or recycled**
	☐9 ☐7 ☐5 ☐3	☐1	☐3 ☐5 ☐7 ☐9

Please Leave your comments, if there is any