SMART AND SUSTAINABLE URBAN DISTRICTS:
ASSESSMENT SYSTEMS AND CASE STUDIES

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ABSTRACT

SMART AND SUSTAINABLE URBAN DISTRICTS: ASSESSMENT SYSTEMS AND CASE STUDIES

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The Smart city concept has become an important strategic planning mechanism in past decade or so, with respect to the combination of sustainability, information and communication technologies for urban development in many countries. This study is aimed at an in depth analysis of the Key Performance Indicators (KPIs) related to the smart city concept and its applicability to urban neighborhoods.

The research is based on case studies in from around the world to determine the instruments of smartness; since the concept itself has wide, fuzzy boundaries, and includes many components for various disciplines that require the input from architects, urban planners, software engineers, and as such. Integration of all, within the architectural design domain is missing in the field. Existing frameworks for Smart Cities, and assessment schemes for urban sustainable neighborhoods were gathered and analyzed in this study. With determined KPIs framework, three different prominent smart city cases, namely, Malmö, Seoul, and Curitiba were studied and assessed. As a self-contained neighborhood example in Turkey, METU was handled as a case, assessment of the campus was done with determined KPIs. Recommendations for the smartization process of campus was presented.

Keywords: Smart cities, Sustainability assessment, Smart city indicators, Urban neighborhoods

ÖZ

AKILLI VE SÜRDÜRÜLEBİLİR KENTSEL YERLEŞİM YERLERİ: DEĞERLENDİRME SİSTEMLERİ VE ÖRNEK ÇALIŞMALAR

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Akıllı kent konsepti pek çok ülkede sürdürülebilirlik, ve bilişim teknolojilerinin birlikte yorumlandığı geçmiş on yılda önem kazanmış bir kentsel planlama mekanizmasıdır. Bu çalışmanın temel amacı akıllı kentlerle ilgili anahtar performans göstergelerinin derinlemesine analizi, ve bunların kentsel çevrelere uygulanabilirliğidir.

Akıllı kent konseptinin oldukça geniş ve bir anlamda belirsiz sınırlara sahip olması, ayrıca mimari, kentsel planlama, yazılım mühendisliği ve buna benzer pek çok disiplinin gerektirdiği bileşenlere sahip olması sabeplerinden ötürü bu çalışma kentsel bağlamda akıllılığın göstergelerine karar vermek için dünya çapındaki vaka çalışmalarını incelemiştir. Bahsedilen faktörlerin bütünleşmesi mimari bağlamda eksiktir. Akıllı kentler için var olan sistemler ve kentsel sürdürülebilir çevreler için tasarlanmış değerlendirme şemaları bir araya getirilerek analiz edilmiştir. Literatürden elde edilen akıllı kent değerlendirme göstergeleri şematize edilerek farklı kıtalardan üç önemli akıllı kent olan Malmö, Soul, ve Curitiba kentleri örnek olarak incelenmiş ve bu tabloya göre değerlendirilmiştir. Türkiye'den kendi içinde yeterli bir yerleşim örneği olan Orta Doğu Teknik Üniversitesi Ankara kampüsü bir vaka çalışması olarak değerlendirilmiş, akıllılaşma süreci için gerekli önlemler önerilmiştir.

Anahtar sözcükler: Akıllı kentler, Sürdürülebilirliğin ölçülmesi, Akıllı kent ölçütleri, Kentsel çevreler

Dedicated to my dear family,

and my beloved husband Cüneyt Öztürk.

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This master thesis is the beginning of my academic journey, and hopefully, all these people will stay in my life forever.

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ABBREVIETIONS

AT: Austria

BRE: Building Research Establishment

BREEAM: Building Research Establishment Environmental Assessment Method

BSI: British Standardization Institution

CEN: The European Committee for Standardization

CENELEC: The European Committee for Electrotechnical Standardization ETSI: European Telecommunications Standards Institute

CO_2: Carbon dioxide

DGNB: Deutsche Gesellschaft für Nachhaltiges Bauen (German: German Sustainable Building Council)

EIP SCC: European Innovation Partnership on Smart Cities and Communities

EU: European Union

FI: Finland

FP7: 7th Framework Programme for Research and Technological Development

GDP: Gross Domestic Product

GFA: Gross Floor Area

HR: Croatia

ICF: Intelligent Community Forum

List of Abbreviations (Continued)

ICLEI: International Council for Local Environmental Initiatives

IEC: International Electrotechnical Commission

IEEE: Institute of Electrical and Electronics Engineers

IoT: Internet of Things

ITU-T: International Telecommunication Union-Telecommunication

JTC 1: Joint Technical Committee 1

KPI: Key Performance Indicators

NL: Netherlands

OECD: Organization for Economic Cooperation and Development

PA: Public Administration

SCC: Smart Cities Council

SMG: Seoul Metropolitan Government

SSC: Smart Sustainable City

STEEP: Systems Thinking for Comprehensive City Efficient Energy Planning

TC: Technical Community

UN: United Nations

UK: United Kingdom

USGBC: United States Green Building Council

WCCD: World Council on City Data

VTT: Valtion Teknillinen Tutkimuskeskus (The Technical Research Centre of Finland)

CHAPTER 1

INTRODUCTION

In this chapter, the argument with the background information of the problem, aim and objectives, procedure, and the disposition of the study is presented.

1.1. Argument

There is an immense increase in awareness regarding environmental degradation and precautions are being taken in terms of public, institutional, and academic level. Interest in environmental research has become widespread and one of the mainstream areas of research are in the field with “green design”, “high-performance buildings”, “sustainable design” and as the like. The name referring to such approaches may change due to slight variations in some characteristics, but the core concern remains the same. In the essence, the idea keeps its individual authenticity.

In this regard there is also a need to identify, and classify the degree of harm that we give to nature, especially through the built environment. The current endeavors continue in a particular direction with certain assumptions, but there is a need to widen the focus. Building energy labeling is a solution regarding the smallest unit of a city, but there are some other factors that come into play when the perspective is enlarged, to the urban scale. On the other hand digitalization has gained momentum in last decade, with the access of smart phones, while most people have become undeniably dependent on digital gadgets. Organizations, institutions, governmental facilities, and all kinds of businesses have become accessible online. From the perspective of the built environment, i.e. buildings and cities, there is an increasing need for creating an integrated approach rather than individual developments. These factors, with many others, leads the issue the “smartization” process of cities.

The use of digital technologies in creating smart or intelligent buildings, smart metering and smart mobility together lead us to the notion of a “Smart City”. Many cities around the world are claiming to be smart but all of them seem to have their own conceptions of smartness; and all of these do not necessarily match with each other.

The main aim of this study, within the perspective of Smart Cities and its domains, is an in depth research and analysis of the concept of smartness in cities. This research does not target a specific area or a region; but its limitations are a result of the limited amount of information available from literature, limited access to data, or even language constraints. Nevertheless, there is a fair amount of sources on the issue such as journal articles, conference proceedings, frameworks of relevant standardization bodies, or reports etc. The concept itself has wide, fuzzy boundaries that include many components for various disciplines, such as architects, urban planners, software engineers, officials and others. Integration of all, within an architectural perspective, is missing in the field. Although there are many researches on the major components and systems for smart cities, there does not seem to be a clear or unique definition of what a smart city should be; what is required to classify a city as “Smart”, and what should be the necessary characteristics. This is the primary research question in this thesis. What makes cities smart and what are the precautions that should be taken or adaptations that should be made for a city to become smart? What can be the “smartization” process of an environment, less smart/sustainable/green communities? A template guideline for any other city might not be an effective and holistic solution. Furthermore, there is not an exact, international guide for each community indeed, but a model can be assembled in national context, within the enlightenment of several case studies. In this sense, a primitive framework will be created to classify the cities, and different models will be analyzed. Adoption and improvements of the specific part of Ankara –as a non-smart city- will be discussed and developed in last two chapter.

1.2 Objectives

Primary objectives of this study are listed below;

- Determination of what is smart, and what is a smart city, based on a literature review,
- What are important smart city transformation examples for environmental sustainability in the real world,
- What can be adopted as the Key Performance Indicators (KPIs) for both a smart and a sustainable city,
- Evaluation of a non-smart neighborhood, according to the selected KPIs,
- Recommendations for converting the case study into a smart neighborhood from an environmental point of view.

1.3 Procedure

With respect to mentioned objectives above, the study starts with the investigation of "What is Smart?" and "How to be Smart?". In this context, necessary background information on Smart Cities and main KPIs which are created with the contribution of relevant authorization bodies, largely-funded project groups, organizations on smart cities, and additionally the sustainability assessment schemes on urban developments were collected through a detailed literature review, and analyzed. Findings from the literature resulted in a framework, which is focused on the built environment, and assesses the smartness of urban neighborhoods.

Furthermore, prominent smart city examples around the world, or the cities being defined as "smart" according to various key performance indicators, or their characteristics are classified, and several of them are studied as cases, considering their transformation in time, with the necessary applications for the smartization process.

Assessment of information collected from meta-studies of each city was done with the help of the determined framework.

After determining the Smart City programs and the green certification systems planned or implemented in the case studies, it is possible to identify which indicators can be proposed for the case study area in Ankara; namely the campus district of Middle East Technical University.

1.4 Disposition

This thesis consists of five chapters;

Chapter 1 contains information on the argument, aim and objectives, procedure of the study, and the disposition of the chapters.

Chapter 2 provides the historical background of the Smart City concept, with related KPIs and sustainability assessment schemes through a survey of the literature.

Chapter 3 presents the materials, and the method of the study.

Chapter 4 covers a Smart City framework based on the assessment of existing smart cities, and the application of appropriate KPIs in the case of METU Ankara campus.

Chapter 5 includes the assessment and comparison between smart city cases and METU case, with the recommendations for METU campus during smartization process.

Chapter 6 is the last chapter that concludes the overall study, and offers recommendations for further studies.

CHAPTER 2

LITERATURE REVIEW

Literature review chapter includes 46 published sources. At first, necessary background information on sustainability and urban sustainability is provided. The dimensions of Smart Cities, Key Performance Indicators that assess smartness & urban sustainability and organizations promoting smart city development.

2.1 Historical Background of Environmental Awareness

In order to understand the standpoint of the idea, the word itself should be understood. As cited in Attman (2010) "The word "Sustain" is derived from the Latin word "*sustinēre*" means to keep in existence, to be capable of being maintained in a certain state or condition." Caradonna (2014) stated that the term sustainability has become common in years and in that process, all of the meaning corresponding to this term is somehow related to natural environment.

It is important to underline that environmental sensitivity existed before the very familiar environmental awareness movements become widespread in AEC industry. According to Krygiel and Nies (2008), there are several examples proves that the ancient people also had a conscious about this subject. First one is the structures of indigenous North Americans that indicated that they were able to accommodate different conditions such as location and climate. Second one is Central Arctic people in Canada who constructed buildings that have wind resistance and thermal mass. Last example is the Red Indian tent called Teepee which is made of organic materials such as plants and animal products which are locally found materials. It is not only lightweight but also thermally efficient considering the heat flow. Adopting a sedentary life could be handled as the first critical point in this regard.

Industrial revolution is another important critical point concerning the development of sustainability movement. Meadows et al. (1992) mentioned that as consequences of the industrial revolution Production gained utmost importance; correspondingly, use of other kind of fuels like coal increased, mine construction, water pumping and transporting have become more crucial. Krygiel and Nies (2008) emphasized the main issue in this point as "Natural resources, in the industrial model, were rarely valued at their true cost. Most natural resources were treated as if they were abundant, unlimited, and inexpensive." The authors also stated that fabrication of materials and components also gained importance. As the technology progressed, new building systems emerged like elevators, heating & cooling systems, and electrical systems. Robinson (2014) underlined that after World War II (WWII) importance of the investment on building trade increased and there was a desire for obtaining the profit as soon as possible, hence Long-term maintenance and operational costs were highly disregarded.

Rachel Carson's book of *Silent Spring* published in 1962 is the first criticism on ecological degradation. Poisons, insecticides and lethal effect of pesticides is some major topics of this work. It reached large masses and the Wilderness Act was passed right after the publication, in 1964. After putting this law into force, 9 million acres of wild terrain was safeguarded and secured in United States. Right after this incident, two things started, Earth Day and U.S. Environmental Protection Agency (EPA).

In 1973, the Organization of Arab Petroleum Exporting Countries (OPEC) imposed an oil embargo depending on various reasons. It reduced the supply and drastically raised the prices. Before this incident, most of the energy related systems were based on nonrenewable resources, mostly petroleum.

According to Robinson (2014), this embargo had a powerful effect on oil prices. After WWII, the prices had remained stable until 1973. However, after the incident, there was a dramatic fluctuation between 1973 and 2011, in general (Figure 2.1.) As a result, it was no longer feasible to count on only one energy source anymore.

There are some other environmental issues that forced humankind to change their perspective; some of them are the Amoco Cadiz oil spill, Love Canal, Exxon Valdez oil spill and the discovery of the Antarctic ozone hole.

In 1987, the World Commission on Environment and Development (WCED) published a report entitled "Our Common Future". It was the last incident that played an important role in the environmental movement. The commission defined sustainable development as;

"… development that meets the needs of the present without compromising the ability of future generations to meet their own needs."(WCED, 1987)

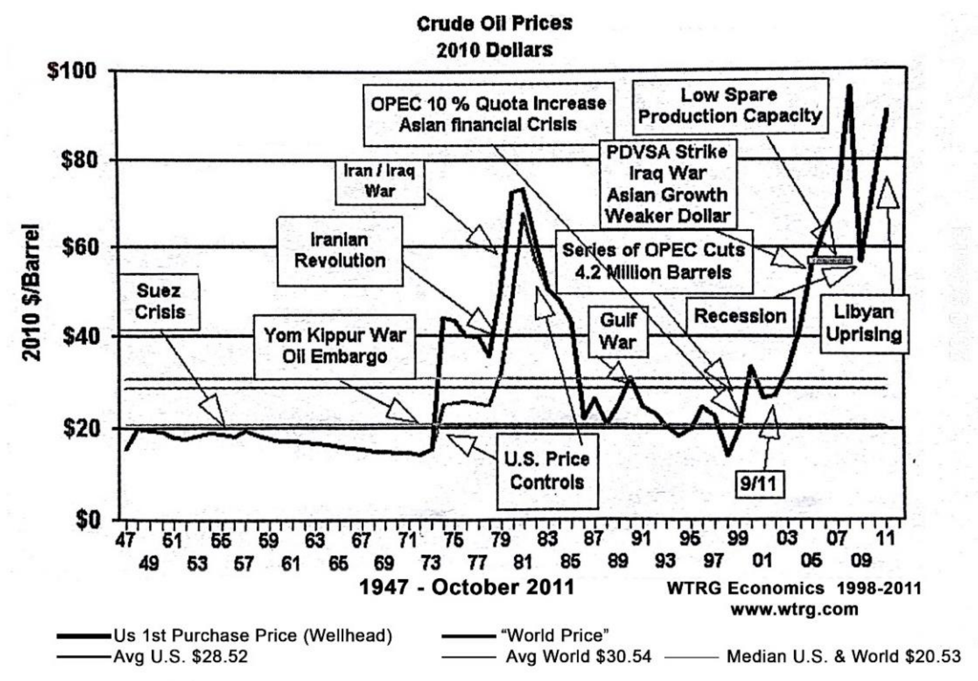


Figure 2. 1 Crude Oil Prices between 1947 and 2011. (Robinson, 2014)

The report emphasizes mainly three crucial topics which are "environmental protection", "economic growth" and "social equity". Resource related problems, fundamental needs like energy, water, food, etc., ascending growth and providing a sustainable level in that sense is some points that are underlined in the report. (As cited in Attman, 2010)

This report caused environmentally sensitive concepts to gain importance and a new period of awareness had begun. Figure 2 represents the increase in the usage of the term “sustainability” in the following years. In this sense, the critical impact of Brundtland Report (1987) can be clearly seen in the graphic (Figure 2.2.).

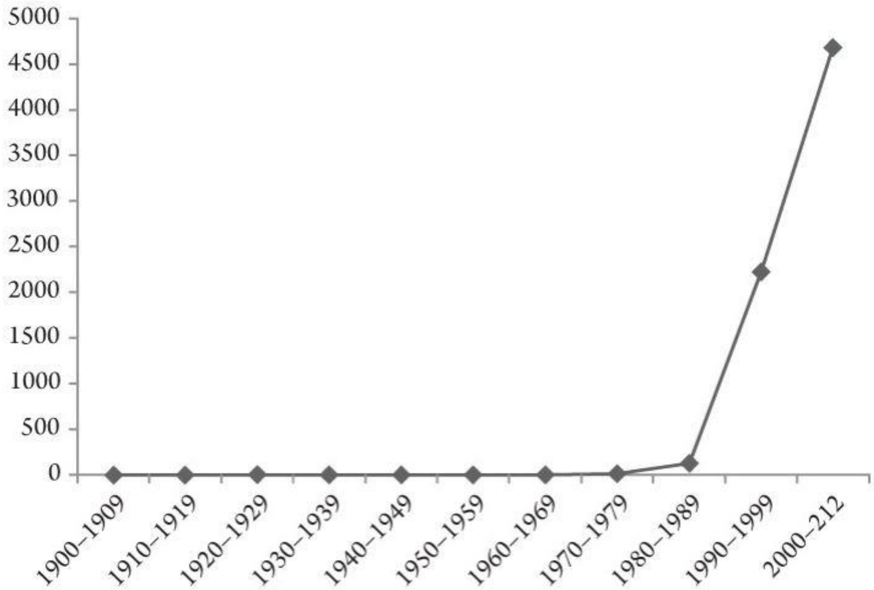


Figure 2. 2 Books with the word “sustainable” or “sustainability” in the title, 1900–2012. (Caradonna, 2014)

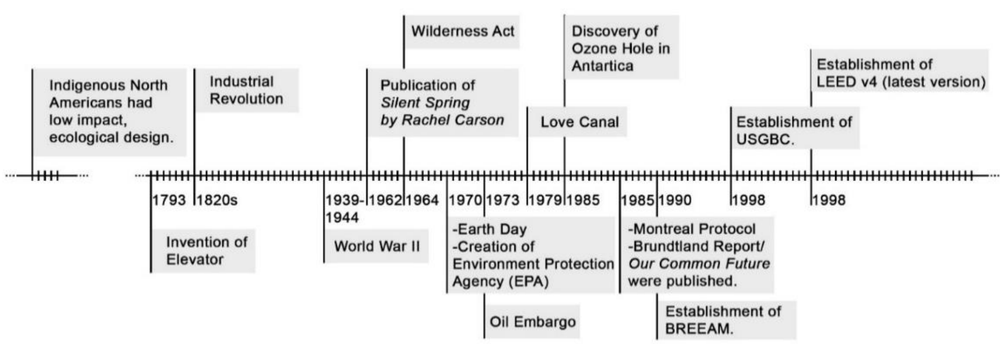


Figure 2. 3 The timeline of important events regarding environmental aspect.

Figure 2.3. is the timeline that illustrates the important events and historical background of environmentally friendly concepts.

2.2. History of Urban Sustainability

Before the influence of environmental consciousness on architectural approach and urban planning concepts with direct "sustainability" label, it has an effect on design and planning criteria. It would be a better approach to investigate Smart City as an isolated case in history, but an integral part of overall, and the current phase of the sustainable urban planning progress around the world. Within this perspective, emergence and development of the various urban planning concepts, which might be related with Smart Cities, will be explained and discussed in this part.

One of the most important urban planning concepts in history was the **Garden City**, created by Ebenezer Howard, after WWII in Britain. Alexander (2009) explained the idea behind the development process of the Garden City. Main concern of the movement is togetherness of urban and rural lifestyle. Primary intent was design of a regular-sized, self-sufficient city, with respect to energy and food supply regarding environmental concerns, containing all kind of activities depending on the need of inhabitants. The idea reflects zoning and a sort of separation between residential and industrial areas with substantial use of green spaces; namely "Green belts", that were utilized for segregation of zones and towns.

Urban Ecology, an antecedent of **Eco-City in** Berkeley, founded by Richard Register and some friends in 1975. It is a non-profit organization and main intention is "rebuilding cities in balance with nature". A "Slow Street" was built in Berkeley with the contribution of Urban Ecology and others. Within the context of various precautions taken, construction of solar houses, energy efficiency (?)-oriented regulations, plantation of fruit trees, transportation oriented solutions to reduce automobile dependency, and conferences related to this movement to raise public interest (Register, 1994). The movement gained importance through academic interest and the first, second, and third International Eco-City Conference were held in Berkeley, Australia, and Senegal, respectively (Roseland, 1997). The concept has various principles, explained by Roseland (1997), such a supportive land use planning with respect to Eco-City aims and revision of necessary parts; "access by proximity" with the promotion of pedestrian, bicycle, and mass transit; remediation of damaged environment; and design of convenient housing in an affordable and safe manner. Besides ecological concerns of Eco-cities, recycling, encouragement of agricultural activities in local and neighborhood scale, and reduction strategies of waste, another principle mentioned by the author is to pay regard to social equality of all citizens, including women, people of different races, and the disabled. Obtaining public attention through activist and informative/educative projects subjected in citizens is the last mission of the concept noted by Roseland (1997).

The Compact City theory is a widely discussed phenomenon in literature that might affect or contribute to the development of sustainable urban city/smart city. It is not a common definition for the term, yet there are fundamental attributes that are noteworthy. Neuman (2005) gathered and described the main characteristics of compact city and states that the first and most mentioned one in literature is about settlement density, especially in residential and employment functions. The second is land use which is a critical point with respect to the usage (small scale parceling) and appropriate mixture of land use; thus, the solid void ratio is high with respect to urban density and open spaces in city. The third is the emphasis on social and economic interactions in this issue. Another critical concern is transportation which should be multi-model within compact city limits. Accessibility and street connection should be in high degrees in both local and regional level, including bicycle roads or sidewalks. Ratio of hard surfaces (might be considered as impervious areas) is quite high. (Neuman, 2005; Arnold and Gibbons, 1996; Burton, 2000; Song and Knaap). Compact city theory can be considered as an antidote to the Urban Sprawl in some ways, which is the expansion of urban pattern in loose densities, segregated functions of the plan, linear growth in commercial usage, resulting with automobile dependency, decline in the focus of a central city (Burchell, et al., 2000).

In an urban context, it is very common for a central settlement's transformation by expansion from the periphery; in other words, growth of center towards its boundaries. Burchell et al. (2000) asserted the main priority of **smart growth** should be the control of the expansion of city on the periphery; and subsequently, "revitalization" of the inner parts of a city, so as to control the direction of population's movements towards the desired focuses. Designing innovations, in terms of attractive focus areas in urban context for social well-being comes in the design considerations of smart community, with the intent of fastening the flow. Another activity that a smart growth particularly involves is resource preservation. Considering the inhabitant movement in different neighborhoods, and effort of reactivation of discredited centers, the concept aimed at compacting the settlement and preventing the waste of resources. Last important activity, outlined by the authors is transportation orientation that provides the supportive urban hub for the transformation process (Burchell, et. al., 2000). The relationship between smart growth and urban sprawl is similar with relationship between compact cities and urban sprawl. In other words, there might be some shared purposes of smart growth and compact cities.

The word **Bioregionalism** is derived from *bio*, which means life in Greek, and *regio*, that stands for the "territory to be ruled". Togetherness of each is interpreted by Sale (1985) as "a life-territory, a place defined by its forms, its topography, and its biota, rather than by human dictates; a region by nature, not legislature." Regarding the natural living in a habitat, bioregion defines our appropriate size of settlement, just like a river basin or water shed. Itis apart from the control of economic or political concerns (Roseland, 1997). The main focus of Bioregional development is on the natural systems, and environments; obtaining the knowledge that explains their working process, and appropriate problem solution techniques of each specific condition of each site (Dodge, 1981). Berg, et al. (1989) underlined the dependency of human-being on natural systems, very similar with vegatational or zoological compounds. The initial idea might have similarities with “Green City” notion, in origin.

2.3. Smart Cities

According to the United Nations Population Fund, in 2008, more than 50% of all people (3.3 billion), lived in urban areas, the number is expected to rise to 70% by 2050, and in Europe, 75% of the population already lives in urban settlements (UN, 2008). The rapid urbanization of towns has great consequences in terms of economy, resource consumption, and environmental performance (Albino et al., 2015). With the massive increase in urban density, consumed energy for electricity, transportation, and lastly the CO_2 emission will increase.

The whole metabolism of the cities usually comprises of 2 elements; input of goods and output of waste, and any problem in this relationship can generate any kind of social and economic problems. Dependence of too many external resources brings its own complications in urban cities (Albino et al., 2015).

Although there is not one rigid definition of “smart city” label, the word “smart” itself emphasizes the “intelligent” or “digitalized” functions of a smart city (Albino et al., 2015). The individual meaning of the word “smart ”can be explained as a sharp intelligence, with a less elitist impression (Nam & Parado, 2011), or cleverness with quick answers/solutions (Stimmel, 2015). There is an attempt to identify ICT based property with a descriptive adjective of a humane characteristic. Quick adaption capacity for the variety of user demands is a prominent necessity for a Smart City (Stimmel, 2015).
There are familiar concepts and “relatives” of smart city in history, which of them were mentioned briefly in previous part. The exact term of “smart” is first used in 90s, when California Institute for Smart Communities first focused on smart communities and the implementation of information technologies in urban design (Alawadhi et al., 2012).

There are various definitions of the “Smart City” term in literature, rather a complete one is;

> Smart City 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. (2014)

Standardization Administration of China (SAC) defined the objectives of smart city development as follows;

- “Convenience of the public services
- Delicacy of city management
- Liveability of living environment
- Smartness of infrastructures
- Long-term effectiveness of network security”

(as cited in BSI, PAS181-Smart City Framework, 2014)

Kondepudi & Kondepudi (2015), conducted a research on smart city attributes and definitions. They analyzed the numerous definitions in the literature (more than 100, Kondepudi & Kondepudi, 2015), and bring together the important keywords on the smart city concept. After collection of Smart City definitions from literature, eight themes characterized the concept best depending on occurrence frequency in relevant sources. The authors summarized the most mentioned themes in literature is firstly; ICT, Communication, Intelligence, and Information theme, with 26% rate.

Infrastructure and Services theme has second place with 18% occurrence rate, and Environment & Sustainability theme with 16% occurrence rate at third place. Other themes are namely; quality of life / lifestyle, people / citizens / society, governance /

management / administration, economy / resources, and mobility (Kondepudi & Kondepudi, 2015).

There are various types of settlements depending on their width and number of inhabitants. According to Doxiadis (1968) settlement hierarchy consists of 11 type of settlement. Smallest component is called isolated dwelling which contains just a few dwellings. The population of Hamlet is less than 100 persons, and has very limited services. Inhabitants of a village is approximately in between 100 and 1,000, and similar with Hamlet, it does not offers most of the services. The population of a town is in between 1,000 to 20,000, and a large town is 20,000 to 100,000. A city has to have a bunch of services and the population is in between 100,000 to 300,000, and the population of a large city is less than 1,000,000. The population of Metropolis is in between 1,000,000 to 3,000,000 and it also includes its suburban settlements, cities, and towns. The population of Conurbation is in between 3,000,000 to 10,000,000, and similar with metropolises, it contains large cities and suburban development. A Megapolis has several Conurbations and has more than 10,000,000 population. Lastly, the term Ecumenopolis is defined by the author to express a theoretical concept to define beyond the growth in population (Doxiadis, 1968).

2.3.1 Dimensions of Smart City

Smartness in city domain has various compounds such as smart economy, smart people, smart governance, smart mobility, smart environment and smart living which is reflected quite often in many sources, especially in EU originated sources. Besides its compounds, there is considerable amount of arguments in literature that assert the relationship between the concept “smartness” and IT infrastructure. Although it is a valuable fact, in this dissertation, the parameters of architectural characteristics in smart cities will be examined and analyzed.

As cited in Harrison et al. (2010), IBM mentioned the expressions of “instrumented, interconnected, and intelligent” stands for the “smart city” concept. The meaning of

“Instrumented” is utilization of sensors, meters, appliances, personal devices, and such kind of similar sensors for gathering and integrating real world data. The word “Interconnected” refers to introducing mentioned data to a platform that allows the communication with other city servers. The word “Intelligent” stands for involvement of complex analytics, modelling, optimization, and visualization services to make better decisions with respect to operational characteristics (Harrison et al., 2010).

Basically, there are 2 main components of smart cities called the hard and soft components; the first consists of buildings, energy grids, water management, waste management, natural resources, logistics, and mobility, and it is named as “hard” components. The second consists of “soft” components, which are, education, policy innovations and makers, culture, social inclusion, where ICT has a determinant role (Neirotti et al, 2014).

Major Key Performance Indicators (KPIs) of smart cities, categorized in a table, as 6 layers of smart cities, which is implemented very often in literature. There are six layers of smart city; the first being the city (as layer 0), which summarizes the smart city concept’s close relation with the context of the city. It includes a conventional city with relevant components, infrastructures, and processes. Layer 1 is green city, depending on new urbanization theories of urban environmental sustainability. Includes energy considerations, water conservation, green transport policies, green building policies, and CO_2 reduction master planning. These are the most crucial topics in a built environment from an architect’s point of view. Second layer is the interconnection layer that forms the city-wide dispersion of green economies. It hosts the “communication pipes”; namely Wi-Fi, radio, Ethernet, and fiber infrastructure. Third layer is the instrumentation layer, which underlines the importance of smart meter’s and infrastructure sensor’s real-time responses in smart cities. Fourth layer is the open integration layer, which emphasizes ICT-related features, i.e. Communication, shared data, content, services, and information. Fifth layer is the application layer, useful for intelligently responsive operation regarding the reflectance of real-time city operations; for example, I-services, I-home, I-energy, I-transport and so on. Sixth layer is the innovation layer which highlights the effect of smart cities' on fertile innovation environment (Zygiaris, 2012) (ISO/IEC JTC 1, 2015). *Figure 2.4.* represents the complete conceptual model of smart city.

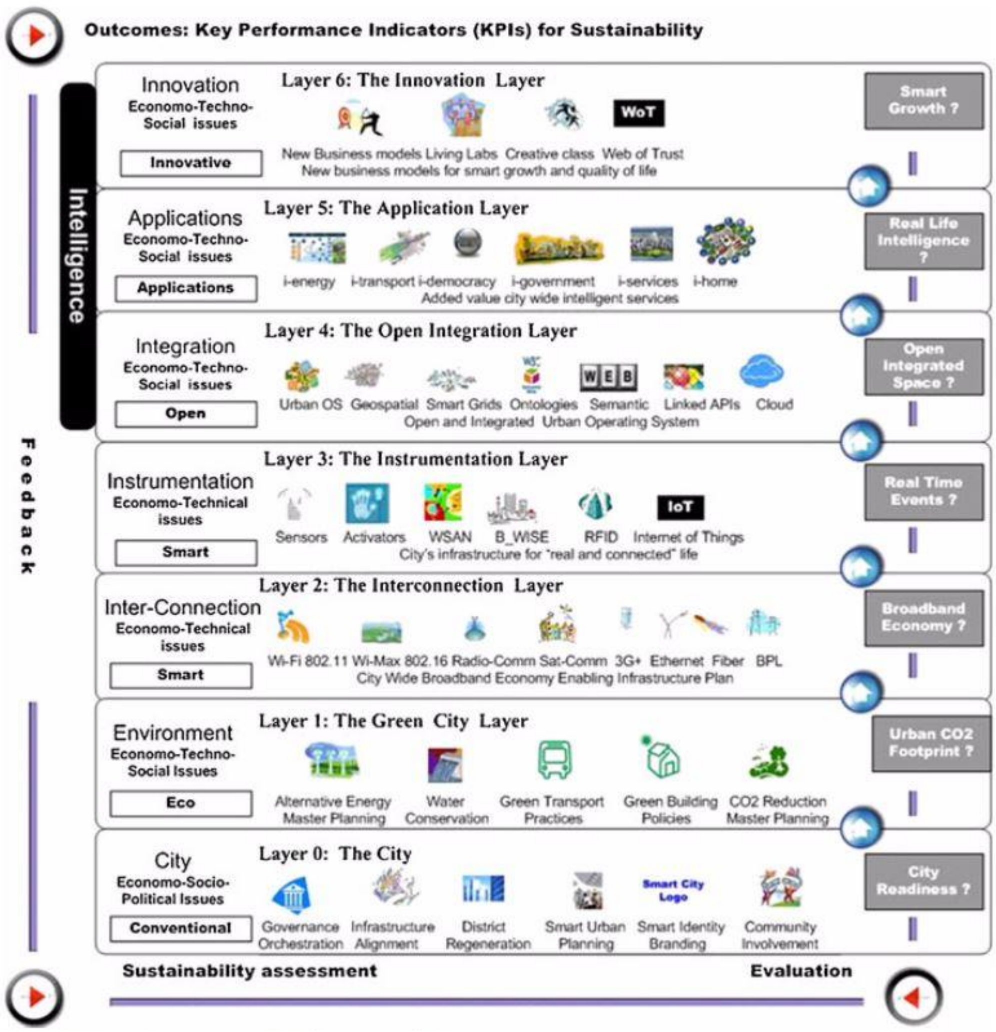


Figure 2. 4 Smart city conceptual reference model. (Zygiaris, 2012)

2.3.2. Indicators of Smart Cities

The definition of Indicator found in literature is: "Anything used to measure the condition of something of interest. Indicators are often used as variables in the modelling of changes in complex environmental systems." (Cumulative Effects Assessment Practitioners' Guide, 2016).

According to Airaksinen (2016), there are many credible indicators for sustainability in the urban scale. Reference Framework for Sustainable Cities; Global City Indicators Facility; and the European Energy Award are some of them. Furthermore, there are several efforts on systematizing the smart city indicators especially in European Cities, although there is no solid framework created for it. Existing available frameworks for smart cities or urban sustainability assessment tools which are summarized in Table 2.1. are presented in this part.

Table 2. 1 Indicators/Assessment Schemes for Smart Cities or Sustainable Neighborhoods.

Name	Developers	Year
CITYkeys	Technical Research Centre of Finland (VTT), Austrian Institute of Technology, Dutch-Indonesian innovation consortium (TNO)	2017
Global City Indicators of ISO	ISO/TR 37150 survey (ISO/IEC JTC 1, 2015)	2014
The Green Index Series of ISO	ISO/TR 37150 survey (ISO/IEC JTC 1, 2015)	2014
Ranking of European Medium-Sized Cities, Centre of Regional Science	Vienna University of Technology, University of Ljubljana, Delft University of Technology	2007
Smart Cities Index Master Indicators	Smart Cities Council (SSC)	2014
Systems Thinking for Comprehensive City Efficient Energy Planning (STEEP)	San Sebastian (Spain), Bristol (UK) and Florence (Italy), ARUP, ATAF, The Centre for Sustainable Energy (CSE), Fomento de San Sebastian (FSS), Acciona infraestructuras, Tecnalia, University of Bristol, and SPES Consulting	2015
LEED-v4 for neighborhood development	USGBC (United States)	2014
BREEAM-Communities	BRE (United Kingdom)	2012
DGNB-NSQ	German Sustainable Building Council (DGNB) (Germany)	2012

2.3.2.1. CITYkeys

The program is derived from European cities and it will implement the monitoring process of smart city progression and relevant strategies. Development of an urban methodology with transparency and uniformity for all forthcoming smart cities for the comparison purpose is a serious necessity (Boni, 2015). Primary purpose of the research group is to develop a base map for data collection principles for future smart cities with respect to the climate and energy target of EU within the scope of HORIZON2020 (Bosch et al., 2017)., which is a largely-funded EU Research and Innovation Programme that aims at smart, sustainable and inclusive economic growth (European Commission, 2008). The evaluation of the solutions depending on performance and success factors in the city's context is critical; for example the effect of energy, environment or economic issues on the human and social development of the city is considered important for the continuity of "Smart City" projects (Boni, 2015).

CITYkeys itself targets the issues pointed out in European Innovation Partnership on Smart Cities and Communities (EIP SCC), and defines the "metrics and indicators" as well as how to "enable cities to demonstrate performance gains in a comparable manner" (Boni, 2015).

The project partners include three main research institutes of Europe; the Technical Research Centre of Finland (VTT) is the project coordinator, and the Austrian Institute of Technology, and the Dutch-Indonesian innovation consortium, TNO are members.

The survey conducted by Neumann et al. (2015), within the scope of CITYkeys, concerns the measurement of the performance of Smart Cities in Europe. The aim of the project is creating "an indicator framework in a bottom-up process, based on the needs of cities" according to their own declaration. The five partner cities that are studied are Rotterdam (NL), Tampere (FI), Vienna (AT), Zagreb (HR), and Zaragoza (ES) (Boni, 2015). Two surveys were designed separately for this study, namely the "Cities' needs" and the "Citizens' and stakeholders' needs". The focus of the former are; “Smart City and Smart City project definitions, Smart City and Smart City project performance measurement, measurement tool properties, data collection and open data” (Neumann et al., 2015), while the latter’s focus is mainly on Smart City project evaluation and acceptance of open data (Neumann et al., 2015).

To create an index from existing frameworks, KPIs, data protocols, and research projects were assessed, as well as the needs of the cities’ and its partners were discussed. A comprehensive examination was held including the 7th Framework Programme for Research and Technological Development (FP7) and HORIZON 2020 projects of EU, and existing Key Performance Indices. *Figure 2.5*. represents the relationship between the smart city domains according to Airaksinen (2016). The classifications of KPIs were basically gathered into three main topics; namely “People”, “Planet”, and “Prosperity”. In this framework, typical “planet” indicators are interrelated with environmental concerns, as in most of the energy-oriented assessment schemes. Besides emphasizing “people” and “property” as being pillars of sustainability (similar to most of the sustainability-related programs), Airaksinen expressed the insufficiency in the criteria related to the scale, multilevel governance, or the capacity of the project depending on applicability. Considering the application process, scalability and replicability have great significance. (Airaksinen, 2016)

The research was conducted on 19 European cities using a questionnaire survey to establish their expectations and needs depending on Smart City performance. The results of the survey on public opinion shows that nearly 50% of the cities do not measure their smart city performance, although around 75% of all consider the concept “Smart City” of high importance (Neumann et al., 2015).

As a result of the questionnaires and research, top five themes on city level are; “Energy, GHG emissions, Transportation, Digital infrastructure and services, Resource management, and Citizen’s participation” according to Neumann et al. (2015). With respect to the project level, top five themes are; “GHG emissions, Energy, Transportation, Digital Infrastructure and services, Environment (air quality, noise, soil, green areas,…), and Quality of Life". The stakeholders' opinions on this issue are; "creation and innovation of knowledge, better public transportation, protection of the environment, better education and skills building, and clean energy" (Neumann et al., 2015).

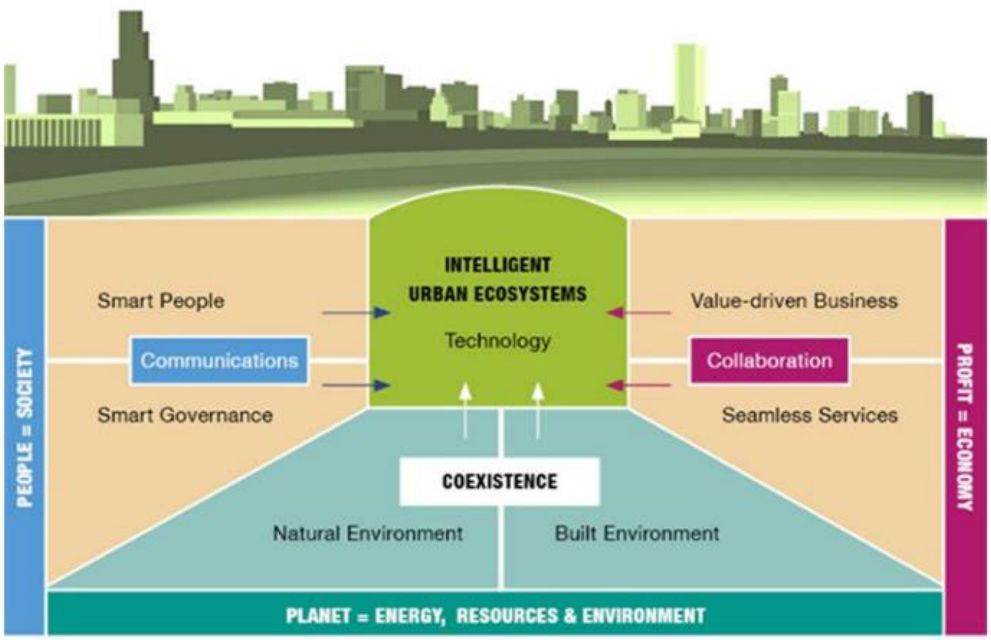


Figure 2. 5 Typical framework of a Smart City (Airaksinen, 2016).

The important lacking issues in existing indices of Smart Cities are namely domestic material consumption, brownfield use, local food production, and urban heat island, considering the Planet theme (Bosch et al., 2017).

2.3.2.2. Global City Indicators and The Green Index Series from ISO/TR 37150 survey

There are physical entities of smart city domain as it was mentioned in ISO/IEC JTC 1's report which was published in 2015. Asset is the first one of them that represents the certain resources that smart cities have. City-Infrastructure is the second one that represents the substructures, namely the water, energy, transportation, and environmental protection infrastructure. Lastly, third one is resources that the city has; for example land, water, or energy.

International Standardization Organization derived ISO/TR 37150:2014 standards on "Smart Community Infrastructures". Main objective is to give an idea about the Key Performance Indices (KPIs) of this community and implement a review. The research was handled by ITU-T Smart and Sustainable Cities Focus Group. (ISO/IEC JTC 1, 2015).

There are various indicators related with separate categories; from education to healthcare facilities. The major ones corresponding with built environment are gathered below, in Table 2.2. (ISO/IEC JTC 1, 2015) First column related with the themes or sub-themes of the chart, while second column has main indicator that the committee designed. Third column has supporting indicators, noted that it is not related or correlated with the indicator in same row, only a list of assistive entry for the theme. Some of the themes has no indicator, but supporting indicator, means there is no primary indicator designed by the committee yet.

Green City Index Series which is covered partially in ISO/IEC JTC 1 (2015) , within the scope of ISO/TR 37150, centers around CO2 footprint, energy, water, and transport issues, that are related with environmental impact of the issue. Table 2.3. presents the indicators of Green City Index Series, 8 main topics and interrelated subtopics in a generic and summarized manner.

Table 2. 2 Global City Indicators for Smart Cities. (ISO/IEC JTC 1, 2015)

Issues / Themes	**Indicator**	**Supporting indicator**
Solid waste	Percentage of city population with regular solid waste collection.	Percentage of the city's solid waste that is disposed of in an incinerator.
	Percentage of city's solid waste that is recycled	Percentage of the city's solid waste that is burned openly.
		Percentage of the city's solid waste that is disposed of in an open dump.
		Percentage of the city's solid waste that is disposed of in a sanitary landfill.
		Percentage of the city's solid waste that is disposed of by other means.
Transportation	Km of high capacity public transit system per 100,000 population	Number of two-wheel motorized vehicles per capita
	Km of light passenger transit system per 100,000 population	Commercial Air Connectivity (number of nonstop commercial air destinations)
	Number of personal automobiles per capita	Transportation fatalities per 100,000 population
		Annual number of public transit trips per capita
Wastewater	Percentage of city population served by	Percentage of the city's wastewater receiving primary treatment
	Percentage of the city's wastewater that has received no treatment	Percentage of the city's wastewater receiving secondary treatment
		Percentage of the city's wastewater receiving tertiary treatment
Water	Percentage of city population with potable water supply service	Total water consumption per capita (liters/day)
	Domestic water consumption per capita (liters/day)	Percentage of water loss
	Percentage of city population with sustainable access to an improved water source	Average annual hours of water service interruption per household
Energy	Percentage of city population with authorized electrical service	Total electrical use per capita (kWh/year)
	Total residential electrical use per capita (kWh/year)	The average number of electrical interruptions per customer per year
		Average length of electrical interruptions (in hours)
Recreation		Square meters of public indoor recreation space per capita
		Square meters of public outdoor recreation space per capita
Environment	PM10 concentration	Greenhouse gas emissions measured in tones per capita

There are other several bodies that are focusing on smart cities and their standards. The technical communities (TC) of International Standardization Organization (ISO) has developed many standards and regulations on sustainable developments around the world. For example; ISO/TC 268 stands directly for the sustainable development in communities. There are several subordinate standards designed under this topic. Firstly, ISO 37101 considers the management systems, and ISO 37120 focuses on

Table 2. 3 Green City Index Series. (ISO/IEC JTC 1, 2015)

Indicator	
CO_2	CO_2 intensity
	CO_2 emissions
	CO_2 reduction strategy
Energy	Energy consumption
	Energy intensity
	Renewable energy consumption
	Clean and Efficient Energy Policies
Buildings	Energy consumption of residential buildings
	Energy-efficient buildings standards
	Energy-efficient buildings initiatives
Transport	Use of non-car transport
	Size of non-car transport network
	Green transport promotion
	Congestion reduction policies
Waste & Land Use	Municipal waste production
	Waste recycling
	Waste reduction policies
	Green land use policies
Water	Water consumption
	System leakages
	Wastewater system treatment
	Water efficiency and treatment policies
Air Quality	Nitrogen dioxide
	Sulphur dioxide
	Ozone
	Particulate matter
	Clean air policies
Environmental Governance	Green action plan
	Green management
	Public participation in green policy

quality of life and sustainability indicators on a global scale, ISO/TR 37150 (which is not available to public access) offers related metrics for smart urban infrastructures, and lastly ISO 37151 is about benchmarking “smartness” of initiatives. (ISO/IEC JTC 1, 2015)

2.3.2.3. Ranking of European Medium-Sized Cities, Centre of Regional Science

EU released a report on the ranking of medium sized Smart Cities, in October 2007, prepared by Giffinger, et al. In recent years, city rating systems have been instrumental in raising awareness regarding sustainability through the assessment of environmental and social factors, in a broader perspective. It is emphasized by the Giffinger et al. (2007) that the innovation or ability of the original supported by improvement of urban progress with historical background and current capability of achieving self-dedicated and efficient urban development, excluding the scale of the city.

Besides academic interest, it also gains the extensive interest of community. The project was conducted on mid-size smart cities in Europe. As importance of city scale was underlined in the report; specification criteria differs in a considerable manner. The research was conducted on 70 smart city from Europe, founded from several different accessible databases, with the population of 100,000-500,000. There are absolute considerations of a smart planning process, mentioned often before. 6 main characteristics of smart city has also used as a baseline in this set. Moreover, there are also factors and indicators that also qualifies and widens the titles (Giffinger, et al., 2007) summarized form of the table is represented in *Table 2.4*. Luxemburg elected in the first place in final. It was noted that economic and publicly related factors. Social and ethnic plurality, open-mindedness, and participation in public life, and language skills of the population has strong contributions on this part. However, some of the noticed indicators are related with the existing capacity of the community. Education level of the people is a long term achievement for a city, and most likely, it is not related with the smart city planning process of the city, which is in brief history of the city.

Table 2. 4 Smart Cities-List of factors and indicators used in the ranking of European medium-sized cities. (Giffinger et al., 2007)

cha	factor	indicator	year	spatial level
Smart Economy	Innovative spirit	R&D expenditure in % of GDP	2003	regional
	Innovative spirit	Employment rate in knowledge-intensive sectors	2004	regional
	Innovative spirit	Patent applications per inhabitant	2003	regional
	Entrepreneurship	Self-employment rate	2001	local
	Entrepreneurship	New businesses registered in proportion of existing companies	2001	local
	Economic image & trademarks	Importance as decision-making centre	2006	regional
	Productivity	GDP per employed person	2001	local
	Flexibility of labour market	Unemployment rate	2005	regional
	Flexibility of labour market	Proportion in part-time employment	2001	local
	International embeddedness	Companies with HQ in the city quoted on the national stock market	2001	local
	International embeddedness	Air transport of passengers	2003	regional
	International embeddedness	Air transport of freight	2003	regional
Smart People	Level of qualification	Importance as knowledge centre	2006	regional
	Level of qualification	Population qualified at levels 5-6 ISCED	2001	local
	Level of qualification	Language skills	2005	national
	Affinity to life long learning	Book loans per resident	2001	local
	Affinity to life long learning	Participation in life-long-learning in %	2005	regional
	Affinity to life long learning	Participation in language courses	2005	national
	Social and ethnic plurality	Share of foreigners	2001	local
	Social and ethnic plurality	Share of nationals born abroad	2001	local
	Flexibility	Perception of getting a new job	2006	national
	Creativity	People working in creative industries	2002	national
	Cosmopolitanism/Open-mindedness	Voters turnout at European elections	2001	local
	Cosmopolitanism/Open-mindedness	Immigration-friendly environment	2006	national
	Cosmopolitanism/Open-mindedness	Knowledge about the EU	2006	national
	Participation in public life	Voters turnout at city elections	2001	local
	Participation in public life	Participation in voluntary work	2004	national
Smart Governance	Participation in decision-making	City representatives per resident	2001	local
	Participation in decision-making	Political activity of inhabitants	2004	national
	Participation in decision-making	Importance of politics for inhabitants	2006	national
	Participation in decision-making	Female city representatives	2001	local
	Public and social services	Expenditure of the municipal per resident in PPS	2001	local
	Public and social services	Children in day care	2001	local
	Public and social services	Perception of quality of schools	2005	national
	Transparent governance	Perception on tranparency of bureaucracy	2005	national
	Transparent governance	Perception on fight agains corruption	2005	national
Smart Mobility	Local accessibility	Public transport network per inhabitant	2001	local
	Local accessibility	Access to public transport	2004	national
	Local accessibility	Quality of public transport	2004	national
	(Inter-)national accessibility	International accessibility	2001	regional
	Availability of ICT-infrastructure	Computers in households	2006	national
	Availability of ICT-infrastructure	Broadband internet access in households	2006	national
	Sustainable, innovative and safe transport systems	Green mobility share	2001	local
	Sustainable, innovative and safe transport systems	Traffic safety	2001	local
	Sustainable, innovative and safe transport systems	Use of economical cars	2006	national
Smart Environment	Attractivity of natural conditions	Sunshine	2001	local
	Attractivity of natural conditions	Green space share	2001	local
	Pollution	Summer smog	2001	local
	Pollution	Particulate matter	2001	local
	Pollution	Fatal chronic lower respiratory diseases	2004	regional
	Environmental protection	Individual efforts on protecting nature	2004	national
	Environmental protection	Opinion on nature protection	2006	national
	Sustainable resource management	Use of water per GDP	2001	local
	Sustainable resource management	Use of electricity per GDP	2001	local
Smart Living	Cultural facilities	Cinema attendance	2001	local
	Cultural facilities	Museums visits	2001	local
	Cultural facilities	Theatre attendance	2001	local
	Health conditions	Life expectancy	2001	local
	Health conditions	Hospital beds per inhabitant	2001	local
	Health conditions	Doctors per inhabitant	2001	local
	Health conditions	Perception on quality of the health system	2004	national
	Individual safety	Crime rate	2001	local
	Individual safety	Death rate by assault	2001-03	regional
	Individual safety	Perception on personal safety	2004	national
	Housing quality	Share of housing fulfilling mininal standards	2001	local
	Housing quality	Average living area per person	2001	local
	Housing quality	Satisfaction with personal housing situation	2004	national
	Education facilities	Students per inhabitant	2001	local
	Education facilities	Access to the educational system	2004	national
	Education facilities	Quality of the educational system	2004	national
	Touristic attractivity	Importance of tourist location	2006	regional
	Touristic attractivity	Overnights per year per resident	2001	local
	Social cohesion	Perception on personal risk of poverty	2006	national
	Social cohesion	Poverty rate	2005	national

One of the important characteristic among 6 is "Smart environment" within the scope of this dissertation, regarding the sustainable point of view. It is examined in three main indicators; namely, attractivity of natural conditions; such as sunshine hours and green space share, pollution, such as summer smog, particulate matter, and fatal chronic lower respiratory diseases, environmental protection, like individual efforts on protecting nature and opinion on nature protection, regarding the public conscious, and sustainable resource management, in terms of use of water per Gross domestic product (GDP), and use of electricity per GDP.

Considering the comprehensiveness of the indicators, KPIs listed by Giffinger et al., which are presented in Table 2.4. are very general in nature. For example, there could be very many factors related to the Smart Environment theme, rather than just "Attractivity of natural conditions, Pollution, Environmental Protection, and Sustainable Resource Management". Further indicators can be derived or detailed; from the point of sustainability in addition to the ones mentioned in this study.

2.3.2.4. Smart Cities Index Master Indicators

Smart Cities Council (SSC) released a table named as Smart Cities Index Master Indicators with the reporting purpose of cities which are selected to the 2014 Smart Cities Index, prepared by Boyd Cohen in 2014. 6 dimensions of smart cities, mentioned in previous part, utilized as sub-categories of table. Environment category works mainly on smart buildings, resource management, and sustainable urban planning areas. At first point, different from EU's indicators, it is reasonable to include to effect of sustainably certified buildings', and smart homes' contribution regarding environmental concern. Secondly, resource management examines energy with respect to renewable energy, total residential energy usage, with reference to ISO 37120 standard, and smart metering. Carbon footprint, air quality, waste generation, and water consumption recognized as a base indicator regarding resource management area.

Lastly, the effect of sustainable urban planning is one of the working areas in SSC's indicators, and it includes climate plan besides green space per capita. However, considering the building scale, whole plan seems focused a little bit more on residential usage. Table 2.5. represents the indicators related with environmental concern (Cohen, 2014). Some of the indicators in the chart have being given a weight, in order to have assess the degree of smartness.

Table 2. 5 Smart Cities Index Master Indicators. (Cohen, 2014)

Working Area	Indicator	Description
Smart Buildings	Sustainability-certified Buildings	Number of LEED or BREAM sustainability certified buildings in the city (Note: if your city uses another standard please indicate)
		% of commercial and industrial buildings with smart meters
		% of commercial buildings with a building automation system
	Smart homes	% of homes (multi-family & single-family) w/ smart meters
Resources Management	Energy	% of total energy derived from renewable sources (ISO 37120: 7.4)
		Total residential energy use per capita (in kWh/yr.) (ISO 37120: 7.1)
		% of municipal grid meeting all of following requirements for smart grid (1. 2-way communication; 2.) Automated control systems for addressing system outages 3.) Real-time information for customers; 4.) Permits distributed generation; 5.) Supports net metering
	Carbon Footprint	Greenhouse gas emissioned measured in tones per capita (ISO 37120: 8.3)
	Air quality	Fine Particular matter 2.5 concentration (µg/m3) (ISO 37120: 8.1)
	Waste Generation	% of city's solid waste that is recycled (ISO 37120: 16.2)
		Total collected municipal solid waste city per capita (in kg) (ISO 37120: 16.3)
	Water consumption	% of commercial buildings with smart water meters
		Total water consumption per capita (liters/day) (ISO 37120: 21.5)
Sustainable Urban Planning	Climate resilience planning	Does your city have a public climate resilience strategy/plan in place? (Y/N) If yes provide link.
	Density	Population weighted density (average densities of the separate census tracts that make up a metro)
	Green Space per capita	Green areas per 100,000 (in m2) (ISO 37120: 19.1)

2.3.2.5. STEEP

Systems Thinking for Comprehensive City Efficient Energy Planning (STEEP) is a project that aims at the development of smart cities and providing an assistance for cities to accomplish their carbon dioxide reduction targets, with FP7 funding of European Commission (STEEP Platform, 2015). The cities where the main partners of this project are San Sebastian (Spain), Bristol (UK) and Florence (Italy). Other partners regarding relevant fields, such as energy, ICT, or transportation were ARUP, ATAF as a public transportation company, the Centre for Sustainable Energy (CSE), Fomento de San Sebastian (FSS), Acciona Infraestructuras, Tecnalia, University of Bristol, and SPES Consulting (STEEP, 2015a). Duration of the project was 2 years, between 2013 and 2015, with the purpose of creation of a framework (KPIs) for smart cities, and in this case the pilot cities were San Sebastian, Bristol and Florence.

Alternative indicators and their selection consists of several steps: analysis of continuously present systems, collection of alternative "themes", creation of the rough outline of the framework from existing available models and partners' opinions, and finally adding the lacking parts, finalization of indicators as a tool for relevant cities, and publication of guidelines and complete methodology (STEEP, 2015b). It is important to emphasize the baselines of the project also depends on existing frameworks, standards, competitions on smart cities, etc. Calculation method of each indicator is exemplified in the List of possible Key Performance Indicators (STEEP, 2015b).

The chart of gathered criticized indicators under six main themes of Smart Cities, and additionally, PA (public authorities), Prosperity: Social, Economy & Finance, and Control themes, are given in Table.2.6. Energy, Mobility and Public Administration (PA) which is related mainly with energy demand of public buildings, are the parameters of the list of indicators that were created by STEEP, and they are mostly taken into consideration in this section. Pollutant and CO_2 emission rates, noise

Table 2. 6 Summarized Smart City Indicators of STEEP (STEEP, 2015a).

Parameter			Mandatory	Supporting measures	Suggested	units
ENERGY	Emissions	CO_2 emissions			total	t/y
			per capita			t/y person
					per sector	t/y
		PM10 emissions			concentration	µg/m3 or days above threshold
		noise pollution			people affected	population subject to noise >55 dB
	Energy	electricity use	per capita			kWh/y person
					per sector	kWh/y
		primary energy	total consumption			kWh/y
	RES	green electricity	total produced			%
			purchased			%
		renewable heat			total produced	%
		renewable energy			electricity + heat	%
	Energy Efficiency	smart meters			electric and heat network	%
		refurbished buildings improving energy performance			retrofittings > EPBD	m2 or %
MOBILITY	Public transport	km of PT per 100,000 inhabitants	lenght of PT per 100.000 inh			km/100,000h
		number of annual PT trips per capita			trips per capita	n/y person
	Private fleet	number of fossil fuelled vehicles per capita	cars			n/ person
			motorbikes			n/ person
					> euro 4	%
	Alternative transport infrastructure	km of bicycle paths per 100,000 population	lenght of bike lanes			km/100000
		number of electric charging stations for EV	number of charging columns			n
		km2 restricted areas	total		pedestrian	km2
					others	km2
ICT	internet connections	number of internet connections per 100,000 population				n/100,000h
		WIFI coverage on public areas				m2 or %
	Infomobility	number of PT stops with real time info				%
		e-ticketing				Y/N or %
	Digitalisation	number of users of digital services				n
		open data set available				n
GOVERNANCE	services efficiency	solid waste production per capita	waste production pro capita			t/y person
		percentage of solid waste recycled	% recycled			%
		liters of water used per capita			use of water pro capita	l/y person
		percentage of water losses in the network			% losses	%
		percentage of waste water under 2-3 treatments			treatments quality	%
	social inclusion	voters at last municipal election	% of eligible population			%
		social housing			% of residential buildings	%
PA	energy consumption of PA	public buildings (electricity)	total		sector/building	kWh/m2 y
		public buildings (gas)				kWh/m2 y
		public fleet	total		per vehicle	kWh/y
		low emission vehicles share	percentage of the total			%
		public lighting	total		km/light	kWh/y
	Renewables	percentage of renewable electricity				%
		percentage of renewable heat				%
		RES power installed				MW
	green public procurement	Commitment to green procurement?				Y/N or %

pollution, electricity and energy consumption, renewable energy and renewable heat production, and overall energy efficiency ratios with reference to smart meter values and energy performance of renovated buildings are measures of the "Energy" parameter. The other parameter named Public Administration includes energy consumption ratio of public buildings in terms of gas, electricity, and energy consumption of transportation both public and private, energy demand of outdoor lighting, renewable energy and heat production, and green product procurement.

2.3.2.6. Urban Sustainability Certificates

In this part, important sustainability assessment certification systems will be mentioned.

LEED

One of the most well-known green building and sustainability rating system in the mainstream is Leadership in Energy and Environmental Design (LEED) certification by United States Green Building Council (USGBC), which was established in 1998. The first pilot version of LEED was released in 1999 (USGBC, 2013), with the categories of "Safeguarding Water" or "Planning Sustainable Sites". In time the certification system were developed by the council, and several rating system for different categories were published, for both building and neighborhood scale. Rating system of the certification consists of Platinum, Gold, Silver, and Bronze labels.

The certification system is very popular among the world; however, the major critical concern is that it has been derived in U.S. regarding the main patterns, public habits, urban problems, and many of others; that's why it is hard to neglect the urban context regarding sustainability assessment. On the other hand, there are some certain assets of program that might contribute to this dissertation.

The essential category of LEED is "Neighborhood Development", fulfilling the urban sustainability demands of the cities. It is an advantage to have detailed and easy to calculate items in score oriented certifications, and LEED is a studied example in this term, despite the negativities. For example, “Tree- lined and shaded Streetscapes” is a credit of Neighborhood Pattern and Design, and it is a to-the-point example regarding landscape design in urban context.

Project checklist of LEED mainly includes such topics, Smart Location & Linkage, Neighborhood Pattern & Design, Green Infrastructure & Buildings, Innovation & Design Processes, and Regional Priority Credits as listed in *Table 2.7*. Wetlands, brownfield remediation activities, and slope protection is site-related factors which is promoted in LEED, while Smart City frameworks are mostly including energy, pollutant, waste, and material related concerns regarding environmental degradation. Furthermore, compact development requirements such as walkable streets, connected and open community, mixed-use planning of neighborhoods, and also the credits related universal design is valuable points of the scheme.

Table 2. 7 LEED v4 for Neighborhood Development Built Project, Project Checklist. (USGBC, 2014)

	Smart Location & Linkage	**28**
Prereq	Smart Location	Required
Prereq	Imperiled Species and Ecological Communities	Required
Prereq	Wetland and Water Body Conservation	Required
Prereq	Agricultural Land Conservation	Required
Prereq	Floodplain Avoidance	Required
Credit	Preferred Locations	10
Credit	Brownfield Remediation	2
Credit	Access to Quality Transit	7
Credit	Bicycle Facilities	2
Credit	Housing and Jobs Proximity	3
Credit	Steep Slope Protection	1
Credit	Site Design for Habitat or Wetland and Water Body Conservation	1
Credit	Restoration of Habitat or Wetlands and Water Bodies	1
Credit	Long-Term Conservation Management of Habitat or Wetlands and Water Bodies	1

	Neighborhood Pattern & Design	**41**
Prereq	Walkable Streets	Required
Prereq	Compact Development	Required
Prereq	Connected and Open Community	Required
Credit	Walkable Streets	9
Credit	Compact Development	6
Credit	Mixed-Use Neighborhoods	4
Credit	Housing Types and Affordability	7
Credit	Reduced Parking Footprint	1
Credit	Connected and Open Community	2
Credit	Transit Facilities	1
Credit	Transportation Demand Management	2
Credit	Access to Civic & Public Space	1
Credit	Access to Recreation Facilities	1
Credit	Visitability and Universal Design	1
Credit	Community Outreach and Involvement	2
Credit	Local Food Production	1
Credit	Tree-Lined and Shaded Streetscapes	2
Credit	Neighborhood Schools	1

	Green Infrastructure & Buildings	**31**
Prereq	Certified Green Building	Required
Prereq	Minimum Building Energy Performance	Required
Prereq	Indoor Water Use Reduction	Required
Prereq	Construction Activity Pollution Prevention	Required
Credit	Certified Green Buildings	5
Credit	Optimize Building Energy Performance	2
Credit	Indoor Water Use Reduction	1
Credit	Outdoor Water Use Reduction	2
Credit	Building Reuse	1
Credit	Historic Resource Preservation and Adaptive Reuse	2
Credit	Minimized Site Disturbance	1
Credit	Rainwater Management	4
Credit	Heat Island Reduction	1
Credit	Solar Orientation	1
Credit	Renewable Energy Production	3
Credit	District Heating and Cooling	2
Credit	Infrastructure Energy Efficiency	1
Credit	Wastewater Management	2
Credit	Recycled and Reused Infrastructure	1
Credit	Solid Waste Management	1
Credit	Light Pollution Reduction	1

	Innovation & Design Process	**6**
Credit	Innovation	5
Credit	LEED® Accredited Professional	1

	Regional Priority Credits	**4**
Credit	Regional Priority Credit: Region Defined	1
Credit	Regional Priority Credit: Region Defined	1
Credit	Regional Priority Credit: Region Defined	1
Credit	Regional Priority Credit: Region Defined	1

BREEAM

Among the sustainability certification systems, Building Research Establishment Environmental Assessment Method (BREEAM) published by Building Research Establishment (BRE) is a quite well-known certification system which is founded in 1990, originated from UK. (Hamedani & Huber, 2012). Labels of the rating system are Outstanding, Excellent, Very Good, Good, and Pass labels. Last version of the BREEAM Communities were released in 2012.

Design and construction phases are interconnected processes that cannot be recognized as separate work items. The whole process should be handled together, and in this respect, post-construction certification is not an effective determination, regarding the critical design decisions that cannot be revised at the later phases of construction. With respect to neighborhood scale, this problem will be more severe and the environmental decisions in built environment will be cursory. In this particular, stages of BREEAM consists of 3 steps that covers very early phases and latter phases of an urban development project. First step named "Step 1-Establishing the principle of development" and it includes strategic decisions for the site. "Step 2- Determining the layout of the development" contains more detailed projections of the organization. "Step 3- Designing the details" includes elaborated work items and detailed design of built environment. Indicators of BREEAM is designed according to this 3 separate stages regarding the different phases of design and construction. Indicators are categorized according to these 3 steps at the BREEAM manual. Besides common energy, water, transportation and this kind of common indicators that frequently appear in the field, effective landscape design promotion, noise or light pollution reduction strategies, flood risk management strategies housing provision, inclusive design / universal design considerations, solar orientation are notable indicators of BREEAM which were adopted the proposed framework.

Governance (GO), Social and Economic Wellbeing (SE), Resources and Energy (RE), Land Use and Ecology (LE), Transport and Movement (TM), Innovation (IN) are the basic categories of this assessment system. Regarding the built environment, Social and Economic Wellbeing, Resources and Energy, Land Use and Ecology, and Transport and Movement are the ones that are taken into account during the evaluation of the proposed scheme. *Table 2.8.* represents the criterion of BREEAM which are listed in BREEAM Communities manual published in 2013.

Table 2. 8 Criterion of BREEAM depending on construction steps. (BRE, 2013)

Step 1: Establishing the principle of development	
GO 01 – Consultation plan	RE 02 – Existing buildings and infrastructure
SE 01 – Economic impact	RE 03 - Water strategy
SE 02 – Demographic needs and priorities	LE 01 – Ecology strategy
SE 03 – Flood risk assessment	LE 02 – Land use
SE 04 – Noise pollution	TM 01 – Transport assessment
RE 01 – Energy strategy	
Step 2: Determining the layout of the development	
GO 02 – Consultation and engagement	SE 12 – Local parking
GO 03 – Design review	SE 13 – Flood risk management
SE 05 – Housing provision	LE 03 – Water pollution
SE 06 – Delivery of services, facilities and amenities	LE 04 – Enhancement of ecological value
SE 07 – Public realm	LE 05 – Landscape
SE 08 – Microclimate	TM 02 – Safe and appealing streets
SE 09 – Utilities	TM 03 – Cycling network
SE 10 – Adapting to climate change	TM 04 – Access to public transport
SE 11 – Green infrastructure	
Step 3: Designing the details	
GO 04 – Community management of facilities	RE 05 – Low impact materials
SE 14 – Local vernacular	RE 06 – Resource efficiency
SE 15 – Inclusive design	RE 07 – Transport carbon emissions
SE 16 – Light pollution	LE 06 – Rainwater harvesting
SE 17 – Labour and skills	TM 05 – Cycling facilities
RE 04 – Sustainable buildings	TM 06 – Public transport facilities

DGNB

DGNB is a sustainability assessment system published by German Sustainable Building Council - New City Districts (DGNB-NSQ, Deutsche Gesellschaft für Nachhaltiges Bauen – Neubau Stadtquartiere), in 2009, note that Germany is an industrial country and construction industry and sustainability awareness is quite active (Hamedani & Huber, 2012). The labels of this system are namely; Gold, Silver, and Bronze.

Weighting: Certification system basically consists of Quality sections as main categories, evaluation topics as subcategories, and criterion from general to specific. Types of Quality Sections are Ecological Quality (ENV), Economical Quality (ECO), Sociocultural & Functional Quality (SOC), Technical Quality (TEC), and Process Quality (PRO). Environmental, Technical, and Sociocultural & Functional Quality are adopted for the proposed framework. Assessment for the each criteria weighted from 1 to 3 depending on priority. According to the comparative research of Hamedani & Huber (2012), DGNB is the strictest certification system to obtain a valid score in comparison with LEED and BREEAM. Some of the adopted indicators for the proposed framework are open space offer, aurban integration & design, inclusive access, art in public space and this sort of design decisions related with urban environment, lifecycle assessment, local food production, and so on. Table 2.9. represents the criterion of DGNB-NSQ.

Table 2. 9 Criterion of DGNB-NSQ. (Retrieved in 8th August 2017, from http://www.dgnb-system.de/fileadmin/en/dgnb_system/schemes/120820_DGNBurbandistricts_Overviewcriteria.pdf?m=1471426110)

Quality Sections	Evaluation Topics	Nr.	Criteria	Weighting	Share of Overall Score
Environmental Quality (ENV)	Global and Local Environmental Impact (ENV10)	ENV1.1	Life Cycle Assessment	3	2,7
		ENV1.2	Water and Soil Protection	2	1,8
		ENV1.3	Changing Urban Microclimate	3	2,7
		ENV1.4	Biodiversity and Interlinking Habitats	2	1,8
		ENV1.5	Considering Possible Impacts on the Environment	2	1,8
	Resource Consumption and Waste Generation (ENV20)	ENV2.1	Land Use	3	2,7
		ENV2.2	Total Primary Energy Demand and Renewable Primary Energy Share	3	2,7
		ENV2.3	Energy-efficient Development Layout	2	1,8
		ENV2.4	Resource-efficient Infrastructure, Earthworks Management	2	1,8
		ENV2.5	Local Food Production	1	0,9
		ENV2.6	Water Circulation Systems	2	1,8
Economic Quality (ECO)	Life Cycle Costs (ECO10)	ECO1.1	Life Cycle Costs	3	6,8
		ECO1.2	Fiscal Effects on the Municipality	2	4,5
	Value Development (ECO20)	ECO2.1	Value Stability	2	4,5
		ECO2.2	Efficient Land Use	3	6,8
Sociocultural and Functional Quality (SOC)	Social Qualities (SOC10)	SOC1.1	Social and Functional Mix	2	1,8
		SOC1.2	Social and Commercial Infrastructure	2	1,8
	Health, Comfort and User-friendliness (SOC20)	SOC2.1	Objective / Subjective Safety	2	1,8
		SOC2.2	Public Space Amenity Value	2	1,8
		SOC2.3	Noise Protection and Sound Insulation	2	1,8
	Functionality (SOC30)	SOC3.1	Open Space Offer	3	2,7
		SOC3.2	Inclusive Access	2	1,8
		SOC3.3	Development Layout and Flexible Use	2	1,8
	Aesthetic Quality (SOC40)	SOC4.1	Urban Integration	3	2,7
		SOC4.2	Urban Design	2	1,8
		SOC4.3	Use of Existing Structures	2	1,8
		SOC4.4	Art in Public Space	1	0,9
Technical Quality (TEC)	Technical Infrastructure (TEC10)	TEC1.1	Energy Technology	2	2,6
		TEC1.2	Efficient Waste Management	2	2,6
		TEC1.3	Rain Water Management	3	4,0
		TEC1.4	Information and Telecomunication Management	1	1,3
	Technical Quality (TEC20)	TEC2.1	Maintenance, Upkeep and Cleaning	2	2,6
	Transport, Mobility (TEC30)	TEC3.1	Quality of Transport Systems	3	4,0
		TEC3.2	Quality of Motor Transport Infrastructure	1	1,3
		TEC3.3	Quality of Public Transport Infrastructure	1	1,3
		TEC3.4	Quality of Bicycle Infrastructure	1	1,3
		TEC3.5	Quality of Pedestrian Infrastructure	1	1,3
Process Quality (PRO)	Participation (PRO10)	PRO1.1	Participation	3	1,7
	Quality of Planning (PRO20)	PRO2.1	Concept Development Process	2	1,1
		PRO2.2	Integrated Planning	3	1,7
		PRO2.3	Municipal Involvement	2	1,1
	Quality of the Management and Construction (PRO30)	PRO3.1	Management	2	1,1
		PRO3.2	Construction Site and Construction Process	2	1,1
		PRO3.3	Marketing	2	1,1
		PRO3.4	Quality Assurance and Monitoring	2	1,1

2.3.2.7. Organizations Promoting Smart City Development

There are many national and international organizations that have started to promote the concept of Smart City. Some of them are developing their own KPIs, others are providing support. A few of them are briefly explained in the following paragraphs.

International Telecommunication Union-Telecommunication (ITU-T) established under the leadership of United Nations (UN), is a specialized institution for development of technical standards, providing technology and network and interconnection in between (ITU, 2017). Smart grid based indicators and sources is published by the union for smart city standardization. There are several foundations that released their individual key performance indicators (KPIs) for smart cities, including ITU-T. It is an open platform for authorized bodies on smart cities, proposing knowledge share and support for integration of ICT services and it is carried out by Study Group 5 (Environment and climate change) (ISO/IEC JTC 1, 2015).

Institute of Electrical and Electronics Engineers (IEEE) is an association which is working in the fields of innovation, networking, generation, automation, operation, and distribution in general. There are various technologies and assistive equipment, in terms of both software and hardware, used in smart urbanization process. Some of them are mentioned in IEEE official website as intelligent lighting, smart building controls, wireless network for automobile charging, transportation sensors, winds turbines and many of such related with Internet of Things (IoT) and Smart Grid (IEEE, 2017). There are several standards, namely road based personal and mass transportation (IEEE P2030.1), discrete and hybrid energy storage systems related with electric power infrastructure (IEEE P2030.2), and test procedures for electric energy storage equipment and electric power systems applications (IEEE P2030.3), created by IEEE related with Smart Interoperability series (ISO/IEC JTC 1, 2015).

European Commission has allocated a considerable amount of funding for the support of Smart Cities. Seventh Framework Programme for Research (FP7) to invest on urban technology solutions and thematic areas which have explicit precedencies, such as ocean preservation, processing of biological resources, energy and raw material usage with better efficiency, etc. (ISO/IEC JTC 1, 2015) European Smart Cities Ranking and Smart 21 are other branches of the European Union on ranking and categorization of smart cities.

Since 2006, the **Intelligent Community Forum (ICF)** encourages intelligent technology and its associated application in the digitalization age of nations (ICF, 2015). Twenty one different smart communities are selected each year, and seven of them are selected within the scope of "Top 7 Intelligent Communities of Year" among Smart 21, and lastly, the highest ranked one is declared the intelligent community of the year. ICF has created an institution consisted of local universities, local governments, and such kind of bodies that are authorized on the formation of communities. The major aim of the institution is creating a knowledge base for the development of regions, cities, or towns for local governmental bodies. There are also 6 distinct main indicators decided by ICF, which are broadband, knowledge workforce, innovation, digital equality, sustainability, and advocacy. The intelligent communities of the past few years were Quebec (2016), Colombus (2015), Toronto (2014), and Taichung City (2013), Riverside (2012), Eindhoven (2011), Suwon (2010), and Stockholm (2009) (ICF, 2015).

CEN / CENELEC (The European Committee for Standardization/the European Committee for Electrotechnical Standardization) and **ETSI** (European Telecommunications Standards Institute), which are the standardization bodies of Europe, is also established a Coordination group on Smart Cities (ISO/IEC JTC 1, 2015), in order to contribute development and standardization of smart sustainable cities and communities while keeping the primary concerns and components of smart cities. The group published a report in January 2015, summarily, descriptions and boundaries of SSC, relevant standardization bodies on smart cities and other countries that conducts a research on their own smart city design process are elemental content of the report. (SSC and Communities Coordination Group, 2015)

British Standardization Institute (BSI) has derived an individual standards strategy, named the Publicly Available Standards (PAS) in several separate parts. It does not only evaluate the necessary indicators in a British context but also in a global level (BSI, PAS181-Smart City Framework, 2014). Some of the publications relevant with smart cities are; PAS 180 Smart Cities Vocabulary, PAS 181 Smart City Framework, PAS 182 Smart City Data Concept Model, PD 8100 on Smart City Overview, PD 8101 Smart Cities, and such kind of other sustainable development related issues.

National Institute of Standards and Technology **(NIST)** works mainly on smart grip appliances; including the collaboration of manufacturers, consumers, energy providers for the achievement of "Interoperability standards" (NIST, 2017). American National Standardization Institute **(ANSI)** has also critical attempts on smart grid issue.

Besides institutions from Europe and America, there are also Asian countries that are aware of smart city initiation and seek the adaption methods for individual contexts. China is one of them that attempted to create distinctive smart cities. **China National IT Standardization TC (NITS)**, and several other authorized bodies are maintaining the development process of standardization work. Current status of Smart Cities in China, relevant standard's needs, necessary terminology, reference, evaluation, and data models, basic indices, and needed methodology throughout the process have been determined and published in reports and books by the committee (ISO/IEC JTC 1, 2015). Korea, India, and several other Asian countries are also working on their own smart city development in terms of definitions and standardizations.

CHAPTER 3

MATERIAL & METHODOLOGY

This chapter includes initial materials and methodology of the study. In materials section, KPIs from the relevant bodies on Smart and Sustainable Cities are given. Methodology process consists of data compilation depending on KPIs, analysis of information regarding the built environment, and a configuration of a final framework that can be tested on smart city cases and a part of Ankara.

3.1. Material of the Study

The material of this study consists of the Smart Cities around the world, and assessment framework of mentioned cities regarding smartness and sustainability.

There are separate notable indicators, created by different standardization bodies, institutions, assemblies, organizations, and so forth, on Smart Cities, which are the primary material in this research. Many of smart cities exist and respective organizations discuss topics / indicators related with target group and the perspective that they have. The important point is that the final assessment framework should be focused on the built environment and implementation of the related characteristics in an urban neighborhood, within the scope of this study. Accordingly, Smart City indicators and linked frameworks, with several assistive sustainable city indicators were assembled; categorized with respect to relevant themes; and condensed in a final chart, including comparable and measurable indicators for each case.

Relevant bodies for Smart City development that are related with the built environment and were gathered from the literature are explained mostly with necessary background information in Chapter 2. The assessment systems used to evaluate them were: CITYkeys; Global City Indicators and The Green Index Series of ISO; Ranking of European Medium-Sized Cities; Centre of Regional Science; Smart Cities Index Master Indicators; STEEP; DGNB-NSQ, BREEAM Communities, and LEED v4 for Neighborhood Development. Some assessment schemes have overlapping indicators, or some indicators are present only one scheme. The source of the indicators are referred in detailed KPI framework, Appendix I. Type of indicator whether it is smart or sustainable is also given in Appendix I, and it is determined depending on the type of source that is referenced from, such as smart city assessment source or sustainability assessment source. Determined 79 main indicators are briefly listed in the following part;

a) Urban Environment

i. Site

- Climate Action Plan
- Historic Resource Preservation And Adaptive Reuse
- Minimized Site Disturbance
- Flood Risk Assessment & Management
- Ecology Strategy
- Connection to Existing Cultural Heritage
- Sense of Place
- Brownfield remediation
- Agricultural Land Conservation
- Local Food Production

ii. Landscape

- Access to green space
- Increased use of ground floors
- Increased access to urban public space
- Tree-lined and shaded street-scapes
- Landscape
- Biodiversity and interlinking habitats
- Density

iii. Urban Pattern

- Compact Development
- Connected and Open community

- Mixed use neighborhoods
- Visibility and Universal Design
- Development layout and flexible use
- Art in public space

iv. Buildings

- Diversity of housing
- Housing provision
- Smart Sustainable buildings
- Building reuse

b) Mobility

- Kilometres of high-capacity public transit system
- Light transit system
- Quality of pedestrian infrastructure
- Number of personal automobiles per capita
- Use of non-car transport
- Access to public transport
- Quality of public transport
- Improved access to vehicle sharing solutions
- (Inter-) national accessibility
- Extending the bike route network
- Access to public amenities
- Clean-Energy Transport
- Access to commercial amenities
- Size of non-car transport network
- Green transport promotion
- Congestion reduction policies
- Sustainable, innovative, and safe transport systems
- Transportation demand management
- Inclusive Access

c) Resources

i. Energy

- Percentage of city population with authorized electric service
- Total residential electrical use
- Increase in local renewable energy production
- Reduction in annual final energy consumption
- Reduction in lifecycle energy use
- District heating and cooling
- Solar orientation
- Increased Efficiency in Resource consumption

- Reduction in embodied energy of products and services used in the product
- Optimizing Building Energy Performance
- Infrastructure Energy Efficiency
- Increase in % of energy produced from the renewable sources

ii. Water

- Reduction in water consumption
- Increase in water reused
- Self-sufficiency - Water
- Percentage of city population with potable water supply service
- Domestic water consumption per capita
- Percentage of city population with sustainable access to an improved water source
- Greywater use and rainwater harvesting

iii. Materials

- Low impact materials
- Life Cycle Assessment
- Share of recycled input materials
- Share of renewable materials
- Share of recyclable materials
- Municipal area Waste Production
- Reduction in the solid waste
- Waste Recycling
- Recycled and Reused infrastructure

d) Pollution

- CO_2 emission reduction
- Decreased emission of NO_x
- Decreased emission of particulate matter PM2,5
- Noise pollution reduction
- Light pollution reduction

KPIs that frequently appeared in literature and the reports of funded projects, research groups, and the works of significant authorization bodies were taken into account in the data collection process of this study. It should also be pointed out that ISO and BSI standards were not accessible due to copyright and funding limitations. For this reason, relevant information was retrieved from citations in literature as in the case of ISO/TR 37150.

3.2. Methodology

This study began with a detailed literature review, which includes a brief history on sustainability and urban sustainability concepts. Main focus is that to understand the basics of smart city concept, and necessary characteristics of a smart city.

Afterwards, Key Performance Indicators of smart cities and well-known sustainability assessment schemes, both of which are specified by various authorization bodies, research groups, or assessment schemes were gathered through the literature. Furthermore, the concept of sustainable cities are also considered as a component in this framework, besides smart cities and its applications, depending on several factors. Firstly, sustainability assessment schemes have appeared in literature much earlier than those for smart cities. For example, BREEAM is the oldest one of these schemes and it was first formulated in the early 90s, whereas the concept of smart city was developed nearly two decades later. In substance, smart cities and sustainable cities are interrelated concepts that evolved and were derived from one another, and should not be handled separately. Secondly, the treatment of these assessment schemes are worldwide, and they have detailed indicators and sub-indicators which gives a comprehensive idea on city assessments regarding sustainability point of view, that is why they were selected.

Obtained information was synthesized and summarized in a framework. The important point in the synthesizing process is that the indicators which are selected to the final scheme are mostly related with built environment. That is why, categorization of the framework was arranged different than the typical smart city KPIs. Instead of “Smart Environment, Smart Mobility, etc.”, these descriptors were utilized: Urban Environment, Mobility, Pollution, and Resources including energy, materials, and water.

A search on the web shows that at least forty-four cities are being defined as “smart” according to various key performance indicators, or their characteristics. 130 of them are located in Europe, 60 are in Asia, 49 in South and North America, 12 in Africa and 3 in Australia. During the collection process of the smart cities from literature; online databases (Smart 21, European Union etc.) and emphasized smart cities in academic sources (journal papers, books, proceedings, etc.) were gathered. The list of Smart Cities are given in Appendix II.

In order to understand the instruments of smartness in built environment, prevalent smart cities were selected as case studies and investigated in depth. The cases of this study is not limited in a specific area, country, or continent. It was attempted to select a city from each continent, such as Malmö from the Europe, Curitiba from South America, and Seoul from Asia, but there cannot enough data found from Africa and Australia. There are also a few smart city initiations in Turkey, which are at the beginning phase. The cases of İstanbul, Eskişehir, and İzmir are briefly explained. In the case of Europe, the information on city profiles, smartness rates, and embraced smart city strategies are larger than every other continents. Articles in literature, various databases, online reports and the websites of cities were used, during the data collection process of cases. Meta of this study consists of an extensive literature search, containing the sources from the official websites of each city, reports from the city’s websites or relevant sources, statistics, and smart sustainable applications of cities referenced in literature, depending on information accessibility within the online medium. The cases were evaluated depending on the final framework. Furthermore, the smartness and sustainability of these cities were assessed, in order to evaluate performance and primary characteristics of a regular smart sustainable city. It should be underlined that the indicators that were gathered from the literature are summarized in a final framework. In the assessment process of cases, existence of indicators were approximately examined, and evaluated in “+”, “-“, or “NI”, which means there is no information found in literature, without an in depth calculation.

Finally, findings of each case will be gathered and discussed. The example of Ankara will be examined with respect to international evaluation tools, regarding Middle East Technical University. The campus of METU is a well-defined, self-contained example in both Turkey and around the world, and has most of the functions that users need in itself. Additionally, there are sustainable campuses around the world, but mentioned characteristics are not compulsory for a university campus.

In this stage, METU campus was investigated depending on the framework that includes smartness sustainability KPIs. The potentials that the campus has already have was presented, in compliance with the framework, and assessment for the further recommendations of the campus are offered.

CHAPTER 4

CASE STUDIES

This chapter includes 3 different cases in Europe, South America, Asia, with 2 Smart City initiation in Turkey. Acknowledged “Smart” cities were investigated considering smartness and sustainability factors, with respect to the integrated framework of this study, in Chapter 2. There are very many different smart cities around the world, the most important concern during the selection process of cases is the indicators that the cities have, depending on suggested framework. In other words, the cities where having more indicators than others were selected as a case. The other determinant factor is the significance of the cities in academic literature. There is no specific region that this study is oriented.

4.1. Malmö

Malmö is the third largest city of Sweden regarding population. It locates at the southern part of the country, where is connected with Copenhagen, Denmark, through Öresund bridge. The municipality is responsible for nearly 300,000 inhabitants in 2013, and the region covers an area of 2,522 km^2 (54 acres) (CAICT & EU-China PDSF, 2014). The density of the city is nearly 119 people per km^2. The climate of the city is oceanic climate. Average temperature of the city varies in between -28 and 34 ^oC. Malmö is a port city, and elevation of it is 12 m above sea level. The city gained 4th place in the “15 Green Cities” ranking of Grist Magazine. Furthermore, the city gained

UN-HABITAT award of United Nations in 2010, RegioStars Awards from European Commissions in first place in 2012, gained third place in Greener Festival Award in 2013, with many other international and national awards (http://malmo.se/Nice-to-know-about-Malmo/Technical-visits/Awards-and-prizes.html).

i. Urban Environment

Bo01 region of Malmö, represented in Figure 4.1., was previously an industrial port, and by the end of 1990s, after the downturn of the company, the site has undergone a transformation within the scope of "City of Tomorrow" housing expo. It is important to note that the site was a brownfield area where the soil was contaminated with aromatic hydrocarbons. The project itself is the first-mixed use development settled in a harbor. It received notable grants mainly for remediation activities, energy-oriented appliances, and building elements; $33.4 million from Swedish government and $2.1 million from European Union (Koch & Kerstig, 2011). Additionally, Öresund Bridge that connects Malmö and Copenhagen with vehicle road and a light rail system has a great effect on the positive transformation of the region, hence fulfilling the requirements for the 1st KPI of Mobility theme that is Light transit system (Austin, 2013).

Previous function of the site was a dockland and the soil was contaminated with aromatic hydrocarbons formerly. As cited in Austin (2013), the City of Malmö reported in 2006 that during the transformation procedure of Bo01 district, approximately 6,000 m^3 of the soil were removed and underwent a treatment removing contaminants. Clean refill was added with 120 thick of topsoil; thus fulfilling the requirements for the 8th KPI: Brownfield remediation, and 3rd KPI: Minimized Site Disturbance.

There is a noticeable amount of public and open spaces in the Bo01 district that provides opportunity for inhabitants to access green spaces, open plazas, recreational activities, and also an "ecological playground" for children; hence the district fulfills 4th KPI of Mobility theme, Access to commercial amenities. (Austin, 2013). Furthermore, each house has various kind of plants, which provide local products for both people and living creatures, thus fulfilling the requirements for 10th KPI: Local Food Production, 15th KPI: Landscape, and 16th KPI: Biodiversity and interlinking habitats (Bo01, Malmö, Sweden, n.d.)

Biological diversity is low in Bo01, depending on the former brownfield activity of site, but habitat replacement was done for approximately 17,800 m^2 area because of the nesting shore birds. Furthermore, a city ecologist works for the neighborhood and the attempts on breeding and growing of native species tolerant of human activity went on; in this way, it is fulfilling 11th KPI: Access to green space, 14th KPI: Tree-lined and shaded street-scapes, and 15th KPI: Landscape, 16th KPI: Biodiversity and interlinking habitats (Austin, 2013).

Figure 4. 1. (Left) The relationship between Bo01 neighborhood with City of Malmö, and (Right) a bird eye view of northern half of Bo01.(Austin, 2013)

Space permeability issue was handled during the design and construction phase, with the help of Green Space Factor that represents the necessary permeability rate of a site that was first designed for the City of Berlin. Surfaces can get 0 to 1 rating depending on type of area; such as 0 for non-permeable surfaces and 1 for fully permeable surfaces like ponds etc. The calculation of total green space factor depends on a reference chart that gives the factor rate of different types of surfaces and total amount of surfaces multiplied with factor rate, than all values are added. The result give the total impermeability score, which is 0.55 for Bo01 (Austin, 2013). Regarding Green Point options, several precautions were taken, such as graveled pavements, buildings with green roofs and storm water ponds consisting mainly of native vegetation (Kruuse, 2011). Figure 4.2. represents the green point applications in Bo01; thus fulfilling the requirements of 15th KPI: Landscape; Resources theme: 19th KPI: Grey water use and rainwater harvesting in Urban Environment theme.

Figure 4. 2. Storm water pond in a courtyard built with regional wetland plants, and green roofs.(Kruuse, 2011)

During the design process of neighborhood, Klas Tham and other 20 different architecture and planning companies, including Santiago Calatrava, with his iconic building Turning Torso, developed the project in terms of material, technological, environmental, and architectural aspects; hence fulfilling the requirements for the 24th KPI: Diversity of Housing) (Givan, 2011). Austin (2013) explains that the periphery of the development consists of larger blocks that surrounds the plot, with smaller and well-organized buildings and courtyards, where plan layout is regulated by a slightly distorted grid. This scheme provides a wind barrier for environmental protection in the harsh climate of Sweden, and allows non-vehicular transportation inside of the built island; hence fulfilling the requirements for the 5th KPI: Ecological Strategy, 7th KPI: Sense of Place, and 19th KPI: Connected and Open Community, 7th KPI: Density, 22nd KPI: Development layout and flexible use in Urban Environment theme; and 11th KPI: Access to Public Amenities in Mobility theme. Setbacks in placements and variety of buildings create a dynamic character, which provides an enriched environment for pedestrians; thus also fulfilling the requirements for the 12th KPI: Increased use of ground floors, and 13th KPI: Increased access to urban public space. Figure 4.3. represents the relationship between Bo01 neighborhood with City of Malmö, and a bird-eye view of northern half of Bo01.

Urban Living Labs of Malmö, similar with other European Smart cities, were acclaimed as a form of participatory/inclusive design regarding the citizens' inclusion, which is mentioned in Bjögvinsson, et al. (2012). The Living Labs project in Malmö started in 2012, and in terms of paying attention on the inclusion of designers, stakeholders, and users in the creation and development progress, while underlining the word of “infrastructuring” rather than “projecting”; thus fuilfilling 19th KPI: Connected and Open Community.

The government of Malmö developed a housing project in one of the low-income neighbothoods of outer city, called Neptuna. Steinfeld & Maisel (2012) mentioned that the housing blocks are designed for elderly people, and the costs of the flat are also appeals to low income groups; thus (Urban Environment, 25th KPI: Housing Provision). The building blocks include social facilities, and recreational spaces, such as eataries, and health-related services, like fitness center and therapy (Steinfeld & Maisel, 2012). Besides provided services of Neptuna housing, universal design measures are employed in interior design of the flats; for example, adaptable heights in sanitary ware, mounted handle bars in the rooms for safety of the elderly, etc. According to Steinfeld & Meisel (2012) Neptuna also has Universal Design treatments in neighborhood scale, regarding accesibility; thus fulfilling the requirements for the 21st KPI: Visibility and Universal Design, 20th KPI: Mixed use neighborhoods in Urban Environment theme and 19th KPI: Inclusive Access in Mobility theme.

City of Malmö has already have a service for the citizens that named as Sommarscen Malmö (Summer scene Malmö), which offers citizens “An outdoor festival of performing arts” (Malmö stad, n.d.). This festival takes place in every 2 months of each summer. The program of the festival includes outdoor performances, cinemas, or concerts presented in various locations in city, and it is free of charge for inclusive participation of the citizens; thus fulfilling the requirements for the 23rd KPI: Art in public space.

Table 4. 1.Assessment of Malmö for Urban Environment theme.

Theme	Sub-Theme	KPI no	Main Indicator	Availability
Urban Environment	Site	1	Climate Action plan	+
		2	Historic resource preservation and adaptive reuse	NI*
		3	Minimized Site Disturbance	+
		4	Flood risk assessment & management	+
		5	Ecology Strategy	+
		6	Connection to existing cultural heritage	NI
		7	Sense of Place	+
		8	Brownfield remediation	+
		9	Agricultural Land Conservation	NI
		10	Local food production	+
	Landscape	11	Access to green space	+
		12	Increased use of ground floors	+
		13	Increased access to urban public space	+
		14	Tree-lined and shaded street-scapes	+
		15	Landscape	+
		16	Biodiversity and interlinking habitats	+
		17	Density	+
	Urban Pattern	18	Compact Development	+
		19	Connected and Open community	+
		20	Mixed use neighborhoods	+
		21	Visibility and Universal Design	+
		22	Development layout and flexible use	+
		23	Art in public space	+
	Building	24	Diversity of Housing	+
		25	Housing Provision	+
		26	Smart Sustainable Buildings	+
		27	Building Reuse	+

** NI: No information.*

Figure 4. 3. The city of Malmö, from an aerial view. (Retrieved in 09.06.2016, from: https://cdn.evbuc.com/eventlogos/14606673/malmophotoprovidedbythemunicipalityofmalmo.jpg)

ii. Mobility

The city has bicycle roads longer than 400 km and approximately 40 % of transportation during rush hours (commuting purposes) is done by bicycle; thus fulfilling the requirements for the 10th KPI, Extending the bike route network (CAICT & EU-China PDSF, 2014). As cited in Austin (2013), the City of Malmö declared in 2006 that a 7-minute walking distance was designed for the residents of Bo01 who are at the most 450 meters (1,500 feet) away from a bus stop. In order to discourage car ownership in Malmö, Bo01 has 0.7 car park ratio for each unit; hence fulfilling the requirements for the 3rd KPI: Quality of pedestrian infrastructure, 4th KPI: Number of personal automobiles per capita, 5th KPI: Use of non-car transport, and 6th KPI: Access to public transport (Givan, 2011). However, this arrangement is not currently corresponding with the demand that is why, a multi-story garage was built beside the Turning Torso (Austin, 2013; Givan, 2011). As cited in Austin (2013), Foletta & Field (2011) mention that nearly half of the inhabitants use busses. Additionally, Malmöstad (n.d.) mentioned that busses have priority in traffic, with the help of intercommunication between bus and traffic light, and waiting period is shorter than private cars. As a result, bus travel gets easy and environmental friendly; thus fulfilling the requirements for the 1st KPI: Kilometers of high-capacity public transit system.

The promotion of bicycle facilities and efforts on the pedestrian movement, from the planning stage of Bo01 district of Malmö is a part of congestion reduction policies. Additionally, the district is fulfilling the requirements for the 16th KPI: Congestion reduction policies.

According to the statistics of Swedish government, the number of vehicles is 119.156, and other than this, the number of environmental cars is 5,189, 2,360 of which registered in 2016 (Vehicles in counties and municipalities, 2017). This means a 50% rise in environmental cars; thus fulfilling the requirements for the 12th KPI: Clean-energy Transport. According to the survey of Swedish National Travel Survey (2017), average time traveled per journey to work is 31 minutes in 2016 (Travel Survey, 2017). The statistics on the performance of train system regarding punctuality in Sweden shows “percentage of the scheduled trains, the day before departure, which arrived terminating station within 5 minutes” is 89%; in this was the city is fulfilling the requirements for the 7th KPI: Quality of public transport, and 14th KPI: Size of non-car transport network in (Train performance, 2017).

Malmöstad (n.d.) mentioned that number of car trips ratio comparing with all trips has decreased from 52% in 2003 to 41% in 2008. There are several other services of the city. At first, Hack Your Energy, is a tool that displays the metered energy data online, with the purpose of better perception of energy consumption. Moreover, with the contribution of citizens, a regional living lab was founded depending on citizen attendance. Green Public Procurement is the second service which aims the employment of green vehicles, including biogas, electric, plug-in hybrid, hydrogen, etc. by 100%, and thus fulfilling the requirements for the 12th KPI: Clean-energy Transport, 15th KPI: Green transport promotion, and 17th KPI: Sustainable, innovative, and safe transport systems. Sweden's first hydrogen car uses the wind energy and has been assigned to all of the employees of Malmö's Environment Department. 50% of public busses uses biogas mostly made from food waste today. Collected food waste from residential kitchens gathered in underground vaults through vacuum shoots is used for the production of biogas (Figure 4.4.), used in public busses or in district heating system; thus fulfilling the requirements for the 25th KPI: Municipal area Waste Production, 24th KPI: Share of recyclable materials, and 23rd KPI: Share of renewable materials in Resources theme. Thirdly, citizens can participate and have a say in the municipal decision making process of the city, with Malmö Panel which is open to online access. (CAICT & PDSD, 2014).

Table 4. 2. Assessment of Malmö for Mobility theme.

KPI no	KPI no	Main Indicator	Availability
Mobility	1	Kilometers of high-capacity public transit system	+
	2	Light transit system	+
	3	Quality of pedestrian infrastructure	+
	4	Number of personal automobiles per capita	+
	5	Use of non-car transport	+
	6	Access to public transport	+
	7	Quality of public transport	+
	8	Improved access to vehicle sharing solutions	NI
	9	(Inter-) national accessibility	NI
	10	Extending the bike route network	+
	11	Access to public amenities	+
	12	Clean-energy Transport	+
	13	Access to commercial amenities	+
	14	Size of non-car transport network	+
	15	Green transport promotion	+
	16	Congestion reduction policies	+
	17	Sustainable, innovative, and safe transport systems	+
	18	Transportation demand management	NI
	19	Inclusive Access	+

** NI: No information.*

Figure 4. 4. Separation of waste using vacuum refuse chutes and environmentally friendly low emission vehicles. (Ritchie and Thomas, 2013)

iii. Resources

There are a few districts for future smart cities as a part of BuildSmart service. The project of Hyllie tested the climate-smart solutions for ventilation, cooling and heating and district received 50 million euros from EU; thus fulfilling the requirements for the 6th KPI: District heating and cooling (CAICT & PDSD, 2014). Secondly, with the opening of a natural gas CHP plant designed by E-ON in 2009, Malmö saw its GHG emissions increase for the first time in a decade. In order to reduce the rates, E-ON decided to employ biogas as a major energy source (Lenhart, et al., 2014), and O'Neill & Rudden (n.d.) mentioned that 50% of the busses in Malmö utilize biogas as a fuel. It is frequently mentioned in the literature that Hyllie district and the city of Malmö is a test ground for new innovative project (Lenhart, Bouteligier, Mol, & Kern, 2014). An aerial image of the district is in Figure 4.6.

The renewable energy of Western Harbor district (in Bo01 region) is provided 100% from solar panel or tube collectors, and wind turbines (City of Malmö, 2005), also with energy efficiency improvements in buildings; hence fulfilling the requirements for the 12th KPI: Increase in % of energy produced from the renewable sources, 3rd KPI: Increase in local renewable energy production, and 4th KPI: Reduction in annual final energy consumption. 1200 m2 flat panel solar collectors, and 200 m2 tube-collectors produces 15% of the energy demand which is necessary to the heating systems and 3 MW Wind turbine utilized for the energy production (Austin, 2013). Figure 4.5. shows the solar tube collectors attached on a building. Furthermore, sea water is used to heat the water during winter, and cool during the summer times, with an aquifer connected to the heat pump (Austin, 2013).

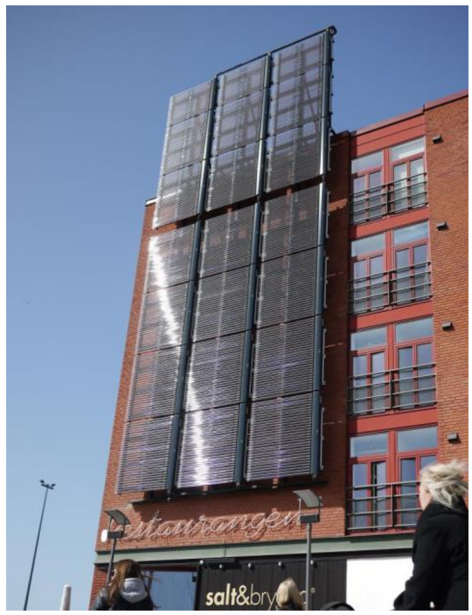


Figure 4. 5. Solar tube collectors, and energy production of the city in Western Harbor district. (Retrieved in 09.06.2016, from: https://www.nfosigw.gov.pl/download/gfx/nfosigw/pl/nfoaktualnosci/1294/3/7/smart_city_malmo_kristoffer_klim.pdf+&cd=5&hl=tr&ct=clnk&gl=tr)

Within the scope of smart city program, BuildSmart project was initiated in Malmö and several other European cities. The aim of the project is reduction of GHG with respect to CO_2 reduction target in climate plan of the city by 2020; hence fulfilling the requirements for the 1st KPI: Climate Energy Plan. In order to accomplish the objective, there were very many strategies were developed and one of them is BuildSmart project (BuildSmart Project Description, n.d.). This initiation subjects reduction of energy consumption in both new constructions and renewal of existing buildings. The target is construction of only net zero buildings by 2021 (BuildSmart Project Description, n.d.). That is why, there are several aspects are taken into consideration, such as "A total very low energy consumption, dense envelopes in order to create a high air tightness and low energy losses, energy efficient installations creating a minimized energy use, heat recovery systems, a high degree of renewable energy production either at the building or in the vicinity, …" as it was declared in project's website (BuildSmart Project Description, n.d.). It is a very complex project which meets 26th KPI: Smart Sustainable Buildings, 27th KPI: Building Reuse of Urban Environment; and 10th KPI: Building Energy Performance of Resources theme. According to Malmöstad (2016), 6 case buildings were constructed in first phase, to observe energy performance with monitoring devices as well as observation of occupant behavior regarding utilization of smart meters or user interface in electronic medium, space comfort of inhabitants, etc.

According to Austin (2013) that 5%-7% of the Bo01 development area includes storm water treatment regarding landscape design, and it planned to improve the quality of water; however, collected water in underground canals and most of the treatment occurred. According to Fraker (2013), gray water that are collected from the courtyard of buildings purified with the help of urban elements and reused; thus fulfilling the requirements for the 14th KPI: Increase in water reused.

As mentioned in the book by Fraker (2013), the material selection for Bo01 development as well as the life cycle assessment of building materials was the developers responsibility and the usage materials on the list of the "National Chemical Inspectorate" is prohibited, as declared by the municipality; hence fulfilling the requirements for 20th KPI: Low impact materials, 21st KPI: Life Cycle Assessment (Fraker, 2013). The author also declared the usage of recycled content in infrastructure during the assessment of Bo01 district of Malmö, with respect to LEED credentials, that is also fulfilling the requirements for 28th KPI: Recycled and Reused infrastructure (Fraker, 2013).

Table 4. 3. Assessment of Malmö for Resources theme.

Theme	Sub-Theme	KPI no	Main Indicator	Availability
Resources	energy	1	Percentage of city population with authorized electric service	NI*
		2	Total residential electrical use	NI
		3	Increase in local **renewable energy** production	+
		4	Reduction in annual final energy consumption	+
		5	Reduction in lifecycle energy use	NI
		6	District heating and cooling	+
		7	Solar orientation	NI
		8	Increased Efficiency in Resource consumption	NI
		9	Reduction in embodied energy of products and services used in the product	NI
		10	Optimizing Building Energy Performance	+
		11	Infrastructure Energy Efficiency	+
		12	Increase in % of energy produced from the renewable sources	+
	water	13	Reduction in water consumption	+
		14	Increase in water reused	+
		15	Self-sufficiency - Water	NI
		16	Percentage of city population with potable water supply service	NI
		17	Domestic water consumption per capita	+
		18	Percentage of city population with sustainable access to an improved water source	NI
		19	Grey water use and rainwater harvesting	+
	materials	20	Low impact materials	+
		21	Life Cycle Assessment	+
		22	Share of recycled input materials	NI
		23	Share of renewable materials	+
		24	Share of recyclable materials	+
		25	Municipal area Waste Production	+
		26	Reduction in the solid waste	NI
		27	Waste Recycling	+
		28	Recycled and Reused infrastructure	+

** NI: No information.*

One of the primary appliances of Malmö and most of other smart cities are monitoring devices, such as water meters, energy monitoring devices, and similar gadgets in individual houses. It is necessary both for obtaining of accessible data, and the awareness of inhabitants. This is a smart city strategy to reduce energy and water consumption on an individual basis, and the city is fulfilling the 4th KPI: Reduction in annual final energy consumption, 13th KPI: Reduction in water consumption, 17th KPI: Domestic water consumption per capita.

Storm water management of the site was designed for 31 inches (787.4 mm) of precipitation which compensates the annual precipitation rate of Malmö. Drainage and filtration of storm water was provided in strategic spots, as a part of water management strategy, and collected water is used for irrigation; thus fulfilling the requirements for 4th KPI: Flood risk assessment & management of Urban Environment theme. Filtration of water is provided with necessary landscape design elements (Austin, 2013).

The companies and all departments in the city have an environmental supervisor for monitoring reason, and a management unit for environmental purpose, while some of them have EMAS or ISO 14001 certification. For the progress towards the objectives in Malmö’s Environment Program, an environmental report is produced which monitors the related departments every year; thus fulfilling the 26th Smart Sustainable Buildings of Urban Environment theme (CAICT & PDSD, 2014).

iv. Pollution

The climate action plan of the city, which is repeatedly mentioned in the literature, will also be completed covering the rise in sea level, temperature change, precipitation change, also with the reduction rate of greenhouse gasses by 40% from 1990 (CAICT & EU-China PDSF, 2014).

Within the scope of energy targets of EU, the municipality will use 100% renewable energy, and city will be climate neutral, which means the elimination of not only CO_2 but also other greenhouse gasses defined in Kyoto protocol, namely methane, sulphur hexafluoride, nitrous oxide, perfluorocarbons, and hydrofluorocarbons (Anonymous, 2008). Personal energy consumption will decrease 20% by 2020 and 20% more by 2030. Regarding energy sources, fossil fuels will be eliminated and renewable energy sources will be in use; hence fulfilling the requirements for 1st KPI: CO_2 emission reduction, 2nd KPI: Decreased emission of NOx, 3rd KPI: Decreased emission of Particulate Matter PM2,5.

O'Neill & Rudden (n.d.) mentioned that the Light Plan of Malmö offers a well-equipped lighting system for the bicycle roads, or pedestrian paths, while using the LED luminaires for energy efficiency, and reduces illumination level in bio-sensitive regions; hence fulfilling the requirements for the 5th KPI: Light Pollution Reduction.

Iversen (2016) mentioned the risks of high noise level in urban context, and measures of Swedish municipality in Malmö. First step regarding the noise reduction target is placement of microphones to assess noise level; thus fulfilling the requirements for the 4th KPI: Noise pollution reduction. Bergsgatan Street, and "Mobile monitoring station" in Nobelvägen, both of which are active arteries of city (Iverson, 2016). The noise level target of Malmö is 30 dBA for indoor noise level during night time, and 55 dBA for outdoor noise level during night time, maximum.

Figure 4. 6. The aerial image of the city of the Hyllie district of Malmö. (Retrieved in 09.06.2016, from: http://mpd.midroc.se/PageFiles/8800/Hyllie20kontor(1).jpg)

Table 4. 4. Assessment of Malmö for Pollution theme.

Theme	KPI no	Main Indicator	Availability
Pollution	1	**CO2 emission** reduction	+
	2	Decreased emission of **NOx**	+
	3	Decreased emission of **Particulate Matter** PM2,5	+
	4	N**oise pollution** reduction	+
	5	Light Pollution reduction	+

4.2. Curitiba

Curitiba is a capital city of Parana that is one of 26 states of Brazil, located in southern part of Brazil. Population of the city is around 1,800,000 in 2015 (http://population.city/brazil/curitiba/). Overall average temperature throughout a year is high in Curitiba. The altitude of the city is 934 meters above sea level (http://www.curitiba.pr.gov.br/idioma/ingles/historia). The city covers 435 km^2 area and density is roughly 4,062 per km^2 (http://www.c40.org/cities/curitiba). Smart Curitiba is one of the Smart 21 cities of Intelligent Community Forum in 2011 and 2012. The city is also a member of the C40 network, which offer services and promote the attempts of cities on climate change.

i. Urban Environment

Overall planning mechanism of Curitiba consists of radial structural corridors (Lindau, et al., n.d.). Typical cross section of the city is named as “trinary system”, which is a street section consists of a main artery at the middle, one arteries of each side, and gradual increase in the building level from outside to inside of main street. A schematic drawing and an aerial view of the city is presented in Figure 4.7. This planning systems brings dense development in focused structural corridors, and less dense areas between the important axis; thus, fulfilling the requirements for 17^{th} KPI: Density, 18^{th} KPI: Compact Development, and 20^{th} KPI: Mixed use neighborhoods. Downtown area of the city is partially closed to the access of private cars. Linear planning scheme was employed in this areas in city planning. Retail and offices are dominant in downtown district, while residential zone is distant from structural corridors. Land use planning is integrated with transportation system and very limited parking space is offered for the central city, thus fulfilling the requirements for 19^{th} KPI: Connected and Open community in Urban Environment theme. Additionally, 3^{rd} KPI: Quality of pedestrian infrastructure, 4^{th} KPI: Number of personal automobiles per capita and 13^{th} KPI: Access to commercial amenities in mobility theme is fulfilled in Curitiba.

Figure 4. 7. A Typical trinary system of Curitiba. (As cited in Lindau et al., n.d.)

It is mentioned in Jochumsen (2014) that urban planning of Curitiba offers considerable amount of green spaces for citizens; 16 parks, 14 forests and more than 1000 green public spaces. The urban layout during 1970s is limited in 1 m^2 green space for each citizen, and with the efforts on the improvement of green areas, the ratio has been increased in years. Today, the city offers 52 m^2 of green space per inhabitant (Jochumsen, 2014). In this way, the city is fulfilling the requirements for 11th KPI:

Access to green space, 13th KPI: Increased access to urban public space, and 15th KPI: Landscape. Regarding native tree species in Curitiba, there is an endangered one, named as Paraná pine (Araucaria angustifolia), and it is protected with law to give damage to this trees. The unit related with environmental protection in Curitiba ministry provides "150,000 endemic cuttings, 16,000 fruit trees and 260,000 flower seeds" and 350,000 cuttings for a botanical garden and three greenhouses (Jochumsen, 2014). Thus, the city is fulfilling the requirements for 16^{th} KPI: Biodiversity and interlinking habitats, and 5^{th} KPI: Ecology Strategy, and 10^{th} KPI: Local food production. The citizens are also involved in tree planting and greening process, and 'Open University' project of the city provides education for inhabitants on environmental protection issue in old busses that were adopted for mobile education. Some of the streets are converted into pedestrian oriented streets, named as "Flower Street" (Jochumsen, 2014), hence, Curitiba is fulfilling the requirements for 7^{th} KPI: Sense of Place, 14^{th} KPI: Tree-lined and shaded street-scapes.

The city of Curitiba initiated urban agriculture program to reduce emissions of GHGs in urban domain. In total, 67 hectares land in different locations is presented to usage of nearly 20,000 citizens per year. The citizens can sell the products that they grow. Additionally, the city organizes various event to enhance the conscious of citizens on agricultural activities, such as "environmental and food awareness workshops for children, farming skills, culture workshops and composting workshops", as it was mentioned in the profile of Curitiba in C40 cities (http://www.c40.org/awards/2016-awards/profiles/109). In this way, the city is fulfilling the requirements for 9^{th} KPI: Agricultural Land Conservation.

According to Souza and Post (2015), Curitiba is a good example of treatment of Universal Design in public transportation, unlike the overall level of development in rest of the Brazil. Accessibility of bus stops and busses were considered during design stage and provided. Figure 4.8. shows the example of a bus stop in Curitiba (Souza & Post, 2016). Every 1,000 person of 21,000 commuter are disabled people in a daily basis (King, 2013). In this way, the city is fulfilling the requirements for 21^{st} KPI: Visibility and Universal Design in Urban Environment theme, and 19^{th} KPI: Inclusive Access in Mobility theme.

Figure 4. 8. The example of a bus stop in Curitiba. (Souza & Post, 2016)

Regarding housing provision of Curitiba, there were several important projects in the past. First one is Municipal Housing Fund which was enacted in 1990 that provides funding to housing for low income. In 1991, 27,000 dwellings was constructed, and innovation and experiment has been regarded in this housing projects. The Technological City of Curitiba has been worked on the design of housing in low costs with good environmental performance, such as thermal properties, acoustical performance, with durable materials. The other research and development project of Curitiba on housing industry is Villages of All Trades that includes residential facility with a workplace. Within the scope of this project 300 houses has been built so far. (https://www.bshf.org/world-habitat-awards/winners-and-finalists/urban-management-in-curitiba-building-full-citizenship/). Furthermore, “My House, My Life” project in Curitiba also targets low-income group of citizens, who live environmentally vulnerable areas, such as river basins. The target was presentation of 18,000 houses for families who were living in this area (Curitiba_Brazil, 2010). In this way, the city is fulfilling the requirements for 25^{th} KPI: Housing Provision, and 24^{th} KPI: Diversity of Housing.

Table 4. 5. Assessment of Curitiba for Urban Environment theme.

Theme	Sub-Theme	KPI no	Main Indicator	Availability
Urban Environment	Site	1	Climate Action plan	+
		2	Historic resource preservation and adaptive reuse	NI*
		3	Minimized Site Disturbance	NI
		4	Flood risk assessment & management	NI
		5	Ecology Strategy	+
		6	Connection to existing cultural heritage	NI
		7	Sense of Place	+
		8	Brownfield remediation	NI
		9	Agricultural Land Conservation	+
		10	Local food production	+
	Landscape	11	Access to green space	+
		12	Increased use of ground floors	+
		13	Increased access to urban public space	+
		14	Tree-lined and shaded street-scapes	+
		15	Landscape	+
		16	Biodiversity and interlinking habitats	+
		17	Density	+
	Urban Pattern	18	Compact Development	+
		19	Connected and Open community	+
		20	Mixed use neighborhoods	+
		21	Visibility and Universal Design	+
		22	Development layout and flexible use	+
		23	Art in public space	NI
	Building	24	Diversity of Housing	+
		25	Housing Provision	+
		26	Smart Sustainable Buildings	NI
		27	Building Reuse	NI

**NI: No Information.*

ii. Mobility

Ojo et al. (2014), mentioned the importance of smart transportation planning for the achievement of sustainability and smartness in Curitiba case, and it is defined as one of the critical success factors of the city.

Institute of Research and Urban Planning of Curitiba (IPPUC- Instituto de Pesquisa e Planejamento Urbano de Curitiba) is an organization that founded in 1971 and aims the development of innovative projects for urban development in an efficient manner. Additionally, free internet access is presented especially for the low-income districts of the city (http://www.intelligentcommunity.org/curitiba_parana).

It was mentioned in digital platform of C40 that Curitiba is one of the prominent smart city example regarding transportation system (Curitiba: A Leader in Transport Innovation, 2015). The city is inventor of Bus Rapid Transport (BRT) system, and now it is used in very many cities, worldwide. Sustainable transportation conscious has settled in Curitiba years ago. In 1970s, with the emergence of subway systems in other countries, the city used same logic in busses, separate lines were designed for only bus transportation. Integration of bus system with other transportation schemes was the main concern in the design of transportation system; thus fulfilling the requirements for 14th KPI: Size of non-car transport network, and 17th KPI: Sustainable, innovative, and safe transport systems. Direct line service was first initiated in 2011, which offers a shorter travel time for longer distances with less stops (Curitiba: A Leader in Transport Innovation, 2015). According to Goodman et al. (2006), 70 percent of Curitiban population uses BRT bus service for daily commuting purposes, hence the city is fulfilling the requirements for 5th KPI: Use of non-car transport. The authors also mention the high frequency of busses in BRT system and high quality of bus stops and stations that are offered to inhabitants (Goodman, Laube, & Schwenk, 2016); in this way, the city is fulfilling the requirements for 6th KPI: Access to public transport, and 7th KPI: Quality of public transport, and 11th KPI: Access to public amenities. According to Twidell and Weil (2015), 85% of the population today (nearly 2 million people) uses public transportation in Curitiba, because of its well-integration with urban context, and it is resulted with energy efficiency regarding transportation system. In this way, the city is fulfilling the requirements for 11th KPI: Infrastructure Energy Efficiency and 5th KPI: Reduction in lifecycle energy use.

The city promotes design and production of environmentally friendly vehicles. The production of electrical busses which can be speed up to 250 kilometers, with 75% less power consumption than similar diesel-powered vehicles, were accomplished in 2014. The city has 3 fully electrical mini-busses and 10 fully electrical cars. The project named "Ecoelétrico" also aims at reduction of GHGs, efficiency in resource consumption, and 82% efficient in fuel consumption, comparing with similar vehicles which uses gasoline. In this way, Curitiba is fulfilling the requirements for
12th KPI: Clean-energy Transport, 15th KPI: Green transport promotion, 16th KPI: Congestion reduction policies, and 17th KPI: Sustainable, innovative, and safe transport systems, also 1st KPI: CO2 emission reduction, 2nd KPI: Decreased emission of NOx, and 3rd KPI: Decreased emission of Particulate Matter PM2,5 in Pollution theme.

Hidalgo & Huizenga (2013) conducted a research on traffic of Latin American countries. Curitiba as 40.41 minutes, and comparing with 15 other Latin American countries, including Buenos Aires, Mexico City, Rio de Janerio, etc., the city has lowest travel time in traffic, and transportation fatalities (Hidalgo & Huizenga, 2013)

The first bicycle lane was built in 1977 to connect one of the new industrial development areas and central part of the city (Duarte, et al., 2014). In following years, city government promoted bicycle lanes and continued the construction of bicycle paths; thus the city is fulfilling the requirements for 10th KPI: Extending bike route network.

From the beginning of 2000s, Curitiba is working on biogas procurement. In 2008, Curitiba produced a bus that uses 100% biodiesel (B100), and in 2009, new "Green Line" was proposed in BRT system, which has 12 Volvo and 6 Scania busses (Carvalho, Mingardo, & Haaren, 2012). In this way, the city is fulfilling the requirements for 12th KPI: Clean energy transport.

Demand management in Curitiba is a considered point in transportation planning. As cited in Shah (2009), the control mechanism of the city based on pursuing traffic growth and managing mass transportation to direct citizens to public transportation. That is why, expanses on road and parking space maintenance is minimized (Shah, 2009). In this way, the city is fulfilling the requirements for 18th KPI: Transportation Demand Management.

Table 4. 6. Assessment of Curitiba for Mobility theme.

KPI no	KPI no	Main Indicator	Availability
Mobility	1	Kilometres of high-capacity public transit system	NI*
	2	Light transit system	NI
	3	Quality of pedestrian infrastructure	+
	4	Number of personal automobiles per capita	+
	5	Use of non-car transport	+
	6	Access to public transport	+
	7	Quality of public transport	+
	8	Improved access to vehicle sharing solutions	NI
	9	(Inter-) national accessibility	NI
	10	Extending the bike route network	+
	11	Access to public amenities	+
	12	Clean-energy Transport	+
	13	Access to commercial amenities	+
	14	Size of non-car transport network	+
	15	Green transport promotion	+
	16	Congestion reduction policies	+
	17	Sustainable, innovative, and safe transport systems	+
	18	Transportation demand management	+
	19	Inclusive Access	+

** NI: No Information.*

iii. Resources

Clean water supply service to inhabitants is nearly 100% and sanitary service is nearly 93% of total population today, as mentioned in Intelligent Community Forum database (ICF) (http://www.intelligentcommunity.org/curitiba_parana). In this way, the city is fulfilling the requirements for 16th KPI: Percentage of city population with potable water supply service.

In 2010, Siemens commissioned Economic Intelligence Unit (EIU) to conduct a research on the sustainability level of 17 leading cities in 8 different countries in South America regarding Green City Index. According to the results of this research, the greenest capital among 17-city is Curitiba. (https://www.siemens.com/press/en/presspicture/?press=/en/presspicture/2010/corporate_communication/2010-11-lam.php). The assessment of the city regarding Green City Index was given in (Curitiba_Brazil, 2010). With respect to "Energy and CO_2" category, amount of CO_2 emission resulted from electric consumption is 70.4 kg per capita -average value in 17-city is 202.2 kg-, while electricity consumption of Curitiba is 743.5 $ -average value in 17-city is 760.7. Primary renewable energy source of the city is "Hydropower" with 84% (Curitiba_Brazil, 2010). In this way, the city is fulfilling the requirements for 3rd KPI: Increase in Local Renewable Energy Production, 4th KPI: Reduction in Annual Final Energy Consumption, 8th KPI: Increased Efficiency in Resource Consumption, and 12th KPI: Increase in % of Energy produced from Renewable Sources. Additionally, another energy strategy of the city includes replacement of light bulbs with energy efficient fluorescent ones, so that the energy efficiency will be increased.

With respect to "Land use and Buildings" category, population density of Curitiba 4,296.2 persons/km^2 that is lower than average value in 17-city -4,503.0 persons/km^2-, and amount of green spaces per person is 51.5 m^2 that is lower than the average value in 17-city - 254.6 m^2 (Curitiba_Brazil, 2010).

With respect to "Waste" category, the percentage of collected, disposed and shared waste is 100.0% which is above the average 96.2%, and amount of generated waste for each person is 473.2 kg in a year, which is higher than the average of 465 kg. Separation of waste is a considered issue in Curitiba, such as hazardous materials, construction &

demolition waste, besides usual categories of paper, glass etc. Reduction in waste generation is an issue that government is working on (Curitiba_Brazil, 2010). In this way, the city is fulfilling the requirements for 24th KPI: Share of recyclable materials, 25th KPI: Municipal area Waste Production, 26th KPI: Reduction in Solid waste, 27th KPI: Waste Recycling, and 22nd KPI: Share of Recycled Input Materials.

With respect to “Water” category, water consumption for each person in Curitiba is 150 liters in a day, which is way more below the average of 264.3 liters; water system leakages are 39.2% in Curitiba, which is higher than average rate of 34.6%; the percentage of population with an access to potable water is 100%; which is above than the average value of 97.5 (Curitiba_Brazil, 2010). In this way, the city is fulfilling the requirements for 16th KPI: Percentage of city population with potable water supply service, 17th KPI: Domestic water consumption per capita. It was mentioned in Curitiba_Brazil (2010) briefly that water policy of the Curitiba also includes several valuable measures which are, monitoring devices for water consumption in buildings, separation of drinking and non-drinking water, and prohibitions for hose pipe irrigations to provide enhancement of water efficiency in the city (Curitiba_Brazil, 2010). However, there is no other source that proves the information, and that is why, the 19th KPI: Grey water use and rainwater harvesting was not scored positively.

With respect to “Sanitation” category, the promotion of wastewater treatment and reduction in water consumption is a well-regarded concern in Curitiba. 92.5% of the citizens have access to sanitation, which is slightly lower than average rate of 93.7, and 98.3% of wastewater in Curitiba have undergone a treatment, which is quite successful rate comparing with the average of 52% (Curitiba_Brazil, 2010). In this way, the city is fulfilling the requirements for 13th KPI: Reduction in water consumption, and 14th KPI: Increase in water reused.

With respect to “Air Quality” category, the success of the city is repeatedly mentioned in relevant sources in literature. NO_2, SO_2, and suspended particulate matter levels, are calculated as 22.5 ug/m^3, 6.6 ug/m^3, and 25.9 ug/m^3 respectively in daily measurements (Curitiba_Brazil, 2010). In this way, the city is fulfilling the requirements for 2nd KPI: Decreased emission of NOx, and 3rd KPI: Decreased emission of Particulate Matter PM2,5.

Table 4. 7. Assessment of Curitiba for Resources theme.

Theme	Sub-Theme	KPI no	Main Indicator	Availability
Resources	energy	1	Percentage of city population with authorized electric service	NI*
		2	Total residential electrical use	NI
		3	Increase in local **renewable energy** production	+
		4	Reduction in annual final energy consumption	+
		5	Reduction in lifecycle energy use	+
		6	District heating and cooling	NI
		7	Solar orientation	NI
		8	Increased Efficiency in Resource consumption	+
		9	Reduction in embodied energy of products and services used in the product	NI
		10	Optimizing Building Energy Performance	NI
		11	Infrastructure Energy Efficiency	+
		12	Increase in % of energy produced from the renewable sources	+
	water	13	Reduction in water consumption	+
		14	Increase in water reused	+
		15	Self-sufficiency - Water	NI
		16	Percentage of city population with potable water supply service	+
		17	Domestic water consumption per capita	+
		18	Percentage of city population with sustainable access to an improved water source	NI
		19	Grey water use and rainwater harvesting	NI
	materials	20	Low impact materials	NI
		21	Life Cycle Assessment	NI
		22	Share of recycled input materials	+
		23	Share of renewable materials	NI
		24	Share of recyclable materials	+
		25	Municipal area Waste Production	+
		26	Reduction in the solid waste	+
		27	Waste Recycling	+
		28	Recycled and Reused infrastructure	NI

** NI: No Information.*

According to Jochumsen (2010) waste recycling is a concerned issue in Curitiba that 70% of waste is recycling by the inhabitants. The author claimed that regarding only the daily paper recycling rate of the city is equal to 1,200 tress (Jochumsen, 2010). In this way, the city is fulfilling the requirements for 24th KPI: Share of recyclable materials, 25th KPI: Municipal area Waste Production, and 27th KPI: Waste Recycling.

iv. Pollution

Congestion reduction policies of Curitiba (mentioned in ii. Mobility section) are fulfilling the requirements for 1st KPI: CO_2 emission reduction, 2nd KPI: Decreased emission of NOx in Pollution theme.

According to the research of Fiedler and Zannin (2015) on traffic related noise pollution, there are 1,314,000 vehicle in Curitiba and 0.73 vehicles per citizen. Measurements of the authors' covers 4 different in situ strips of Curitiba, and the results show that while the municipal noise legislation (Curitiba Municipal Law No. 10.6253at 3, Fiedler & Zannin, 2015) is 65 dB for urban environments, like vehicular roads. The noise limit of municipality is 55 dB for sensitive areas, like schools and hospitals. The measurements were done at 232 different points in this research, and the results reveal that only 45 points below 65 dB rate (Fiedler & Zannin, 2015), which is a very limited area in urban context.

Table 4. 8. Assessment of Curitiba for Pollution theme.

Theme	KPI no	Main Indicator	Availability
Pollution	1	**CO2 emission** reduction	+
	2	Decreased emission of **NOx**	+
	3	Decreased emission of **Particulate Matter** PM2,5	+
	4	N**oise pollution** reduction	-
	5	Light Pollution reduction	NI*

** NI: No Information.*

4.3. Seoul

One of the prevailing cities in Asian context, Seoul is capital city of Korea, where has approximately 10 million population (Beaverstock, et al., 1997), and 605 km^2 built up area. Population density in Seoul is 16,840 person for each km^2 (Kim, H.M., & Han, S.S., 2012), and it is a quite dense data comparing with other parts of Korea and other similar capital metropolis' among the world. The Hangang River located at the center of the city and divide the city into two. There is humid subtropical, and humid continental climate is seen in the city, with 28.6 C° average high during summer time, and −5.9 C° average low during winter time. Elevation of the city is 38 meters above sea level. According to Münzner (2016), Seoul gained 7^{th} place in Sustainable Cities Index Series of ECOURBANHUB. (Münzner, 2016).

Smart city initiation of Seoul was first attempted in 2015, with the "Seoul, a city of happy citizens and a city beloved by the world!" phrase, according to own expressions of government (Smart Seoul 2015, 2015). Open data practice, similar with many other smart cities, are also initiated in Seoul. Governmental data is shared with the citizens, who can see and create graphical expressions with datasets (Yimin, Wong, & Mi).

i. Urban Environment

Seoul Metropolitan Government set several goals within the scope of it climate action plan. The president of International Council for Local Environmental Initiatives (ICLEI), and Mayor of SMG Park Won-soon declared the climate targets in ICLEI World Congress 2015. The most important actions of ICLEI are keeping the global warming under 2 °C, reduction of CO_2 emission rates, resource efficiency, and achievement of EcoMobility, Smartness, biodiversity, inclusiveness, etc. (SMG, 2017). In this way, the city is fulfilling the requirements for 1^{st} KPI: Climate Action Plan.

Cheonggyecheon is a historical district in Seoul with is close with the central business district. Restoration of the site is an extensive investment which caused oppositions in some quarters. Formerly, there was an elevated highway above a stream with post-war bridges. Within the scope of the restoration project, the highway was removed and the district have been transformed into an urban plaza, where 60,000 people in a day uses the district now (Yi & Jung, 2017). Historical values of the stream are historical bridges, and stone walls. However, due to flooding risk, and the large traffic volume at the site, SMG decided to reconstruct the historical elements nearby the original locations (Yi & Jung, 2017), which can be questionable method regarding preservation of the original value. At the end, construction of the restoration of the stream was finished in 2005. As cited in Yi & Yun (2017), a survey was conducted on citizens in 2013, and the results shown that more than half of the inhabitants consider that there were a decrease in bad odor, and noise level, while there were an increase in air quality, water quality and sunlight. In this way, the city is fulfilling the requirements for 2nd KPI: Historic resource preservation and adaptive reuse, 4th KPI: Flood risk assessment & management, 6th KPI: Connection to existing cultural heritage, 7th KPI: Sense of Place, and 11th KPI: Access to Green Space.

Nanjido is a district in Seoul, where various kind of flowers raised, but at the end of 1970s, the place was transformed into garbage dumping site. The district was used in waste dumping purpose 15 years, and in 2010, it was turned into an environmentally friendly place with the efforts of SMG. Current name of the place is World Cup Park, and it hosts very many plant and species. During transformation process, land remediation was required to eliminate the effects of garbage that polluted ground. Besides water purifying plantations, river ecology observation trails, and wetlands were built to struggle with the results of previous function of the site (Yoo, Kim, & Kang, Modularization of Korea’s Development Experience: Nanjido Eco Park Restoration from Waste Dumping Site, 2014). In this manner, the city is fulfilling the requirements for the 5th KPI: Ecology Strategy, 11th KPI: Access to green space, 8th KPI: Brownfield remediation, and 16th KPI: Biodiversity and interlinking habitats.

The attempts of SMG on the Universal Design of public spaces, such as parks, plazas, roads, and public buildings. Zigzag roads for the reduction of vehicle speeds, necessary sanitary room appliances in public WCs, appliances for the accessibility of disabled to parks and plazas, are some of the precautions that SMG have for increase in accessibility and execution of universal design (http://english.seoul.go.kr/creating-universal-design-city/). In this way, the city is fulfilling the requirements for the 21st KPI: Visibility and Universal Design.

Table 4. 9. Assessment of Seoul for Urban Environment theme.

Theme	Sub-theme	KPI no	Main Indicator	Availability
Urban Environment	Site	1	Climate Action plan	+
		2	Historic resource preservation and adaptive reuse	+
		3	Minimized Site Disturbance	NI*
		4	Flood risk assessment & management	+
		5	Ecology Strategy	+
		6	Connection to existing cultural heritage	+
		7	Sense of Place	+
		8	Brownfield remediation	+
		9	Agricultural Land Conservation	NI
		10	Local food production	NI
	Landscape	11	Access to green space	+
		12	Increased use of ground floors	+
		13	Increased access to urban public space	+
		14	Tree-lined and shaded street-scapes	NI
		15	Landscape	+
		16	Biodiversity and interlinking habitats	+
		17	Density	+
	Urban Pattern	18	Compact Development	+
		19	Connected and Open community	+
		20	Mixed use neighborhoods	+
		21	Visibility and Universal Design	+
		22	Development layout and flexible use	NI
		23	Art in public space	+
	Building	24	Diversity of Housing	+
		25	Housing Provision	+
		26	Smart Sustainable Buildings	NI
		27	Building Reuse	NI

** NI: No Information.*

There are various public housing initiations of SMG to provide citizens of various income level. Shift is one of the examples of housing provision of SMG. It is a long term leasing which is called "jeonse", and this service receives funding from relevant departments of government (Seoul, 2015). In this way, the city is fulfilling the requirements for 25th KPI: Housing Provision. 24th KPI: Diversity of Housing.

The greenbelt of Seoul is first initiated in 1970s, during the North – South Korea war. According to Bengston and Youn (2006), there are several reasons to the formation of the belt, which are protection of inner city, prevention of uncontrolled settlements at the outskirts of the city, controlling the growth of the city and prevention of uncontrolled urban sprawl, and the objective of environmental resource preservation. The authors continues with the benefits of greenbelt: several services that the greenbelt is offered, which are flood control, natural habitat protection, increase in air and water quality; recreational spaces of the initiation in extensive wideness; and financial reductions in infrastructural costs regarding a dense development (Bengston & Youn, 2006). In this way, the city is fulfilling the requirements for 4th KPI: Flood Risk Assessment & Management, 17th KPI: Density, and 16th KPI: Biodiversity and Interlinking Habitats.

ii. Mobility

The railway system of the city was built in 1974, and since then, it was operated. Now the length of subway system is 312 km in total, with 270 stations and 9 rail line, thus fulfilling the requirements for 2nd KPI: Light Transit System, 6th KPI: Access to Public Transport, and 7th KPI: Quality of Public Transport. Moreover, in order to reduce vehicular traffic, Seoul Metropolitan Government (SMG) built a lane on the vehicular roads, which is only open to buss access, and added a bus system to subway for easy transfer of the travelers (Kim & Han, 2012). According to Chua (2016), the transportation policies of Korea is highly depended on cars in previous years, but in time, it was understood that it is not a reasonable solution, considering the fulfillment of demand. In 2004, the government handled the bus system for a better development, regarding environmental point of view, demand in citizens, and financial concerns.

Still, 56% energy consumption resulted by passenger trips made by personal cars, which is 26%, as of 2010 (Chua, 2016). There are several policies on reduction in car dependency and transportation enhancement in Seoul, which includes increase in the priority of cyclists and pedestrians in traffic, reduction of congestion rates arise from transportation, promotion of rail-oriented transportation in public concern, and reduction of car dependency to the lowest point possible, and they are represented in Figure 4.9 (Chua, 2016). Furthermore, "Seoul: easily accessible and enjoyable without a car" is a key scheme that Metropolitan Government was adopted, and set the Smart City targets around it. In this way, the city is fulfilling the requirements for 5th KPI: Use of non-car transport. Transportation goals of government, named "2030 Triple 30", also subjects transportation oriented goals, which are "30% reduction in automobile use, a 30% reduction in public transit travel time and an increase in the green space ratio in the CBD from 10% to 30%" according to Chua (2016). The author continues with the results of this goals means 10% increase in green transport share (70% in current condition and 80% the future target), reduction of CO_2 emission rates from 1,2 tons per capita to 0,9 tons per capita for each year (Chua, 2016). Figure 4.10. represents "2030 Triple 30" goals in a detailed manner. In this way, the city is fulfilling the requirements for the 17th KPI: Sustainable, Innovative, and Safe Transport Systems.

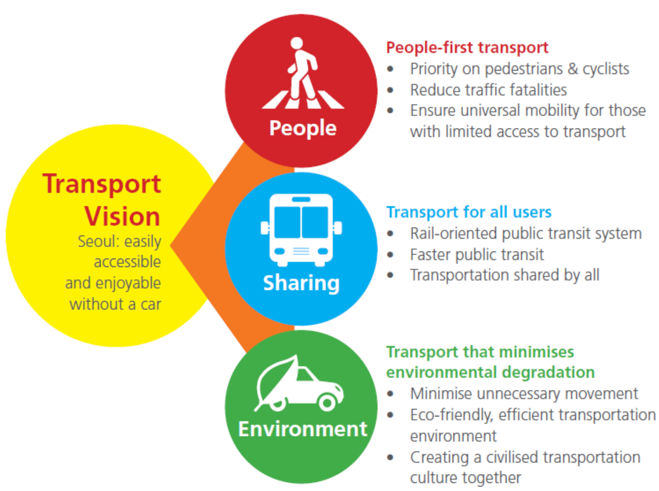


Figure 4. 9.Seoul's Transport Vision and Policy.(Chua, 2016)

There are several strategies developed by SMG, in order to reduce private car-dependency of citizens, and execute the “2030 Triple 30” goals. Urban Traffic Readjustment Promotion Act was also enacted. First strategy on congestion reduction is “Congestion Impact Fee”, which commissioned first in 1990. It subjects the facilities the floor of wherein greater than 1,000 m^2 in total (Chua, 2016). Second strategy is called “Weekly no-driving-day”, and it commissioned first in July 2003. It offers no car usage in one weekday out of five, and the citizens who attend to this program receives 30% discount in “Congestion Impact Fee”, and 20% discount in parking spots. By 2012, nearly half percent of registered vehicles in Korea was engaged in this strategy, and it helps in reduction of 1.1% of traffic volume by 2014, declared in a research conducted by City of Seoul (Chua, 2016); thus, the city is fulfilling the requirements for 16th KPI: Congestion Reduction Policies. Third strategy named “Travel Demand Management (TDM)”. The companies engaged in this program, who adopt measures related with the traffic volume reduction, such as bicycle trip promotion, receives a reduction from congestion impact fee; hence the city is fulfilling the requirements for the 18th KPI: Transportation Demand Management, and 15th KPI: Green Transport Promotion.

A transit mall is usually defined as a commercial area where the vehicular access does not allowed. In the case of Seoul, it is namely Yonsei-ro Transit Mall, where is 550 meters long, and located at the Sinchon district (Hee & Dunn, 2017). The authors continues with prohibition of traffic access gradually in this district, since 2014, and now, it is only open to public transportation. After 6 months, traffic accidents decreased 34% and also it positively affected retail revenue with usage of public transportation (Hee & Dunn, 2017). In this way, the city is fulfilling the requirements for the 3rd KPI: Quality of Pedestrian Infrastructure 11th KPI: Access to Public Amenities, and 13th KPI: Access to Commercial Amenities in Mobility theme, and also, 12th KPI: Increased Use of Ground Floors, and 19th KPI: Connected and Open Community in Urban Environment theme. Figure 4.11. represents an aerial image taken before and after this practice.

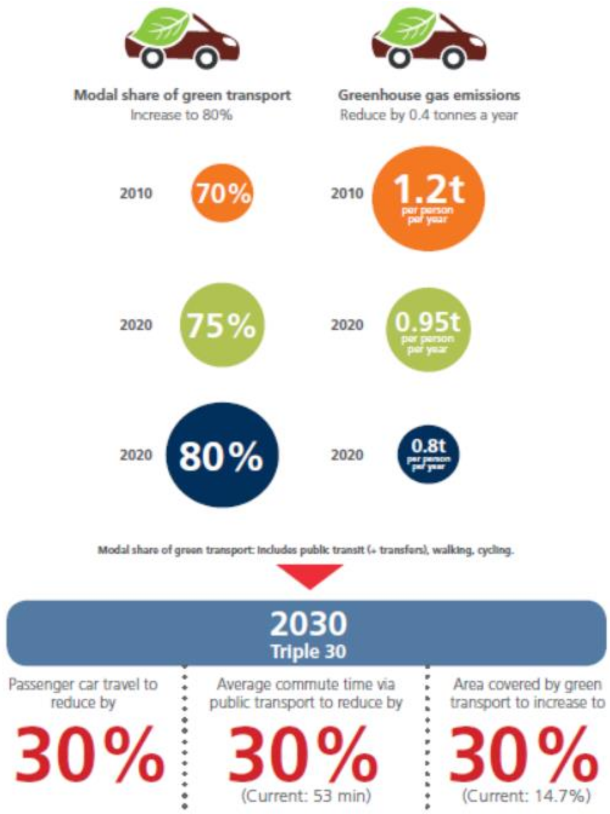


Figure 4. 10. Triple 30 targets of Seoul Metropolitan Government.(Chua, 2016).

In the transformation process of Yonsei-ro, there are several initiative. Firstly, half of the road lanes were eliminated regarding "Road Diet" regulation. Pedestrian paths were widened up to 8 meters to present the necessities for pedestrian-oriented development. The obstacles that prevents the movement of pedestrian flow was removed or relocated, i.e. electrical boxes. In order to create a enhance wheelchair access, curbstones was removed in this district, therefore there is no level difference between sidewalk and vehicular road. Furthermore, it is allowed to perform cultural events without any permissions, in order to support citizens to participate these events (Yi & Jung, 2017). In this way, the city is fulfilling the requirements for and 23rd KPI: Art in Public Space, and 13th KPI: Increased Access to Urban Public Space, 18th KPI: Compact Development in Urban Environment theme.

A research was conducted by Byun et. al. (2017), to measure inclusiveness rate of Seoul. There were 6 dimensions and 33 indicators handled to cover Human Inclusiveness, Spatial Inclusiveness, and Governance Inclusiveness. Within the scope of the research, inclusiveness of Seoul was compared with Organization for Economic Cooperation and Development (OECD) average inclusiveness rate in cities, and only in 1 category, which is "Economic Competence dimension within the Human Inclusiveness", Seoul is higher than the average. In other categories, the score of the city is poorly lower (Byun, et al., 2017). Furthermore, citizens of Seoul also evaluated the inclusiveness of city low. According to the results of questionnaires, 49% of the citizens consider inclusiveness of the city is lower than 5 years ago, with respect to economic, and social terms while 16.2% thinks opposite (Byun, et al., 2017). That is why, the city has efforts on improving accessibility; however, it is not fulfilling the requirements for 19th KPI: Inclusive Access.

The city of Seoul has already had a bike service before the initiation of Ttarungi Bike-share project. Jang (2014) mentioned that a pilot study of this initiation, in Sangam-dong obtained 440 bicycles with 43 stations in 2010, nearly 585 bicycle were in use in 2012, at the same district, but then, the number went in a decline depending on insufficiency in bicycle lanes and stations (As cited in Chua, 2016). The author continues with the initiation of Ttarungi project first in 2015, with 150 stations open to bike share, and nearly 2,000 bikes that was put on the public usage, in order to enhance the usage, several strategies developed; such as, the selection of target neighborhoods with appropriate site characteristic regarding low slope, getting expert opinion on development area, and then arranging the final adjustments. Additionally, "Walk & Bike Festival", "Car-free Zones" are the strategies that promote a pollution free transportation system in Seoul, Korea. In this way, the city is fulfilling the requirements for the 10th KPI: Extending Bike Route Network, and 14th KPI: Size of Non-Car Transport Network, and 1st KPI: Kilometers of High-capacity Public Transit System.

Table 4. 10. Assessment of Seoul for Mobility theme.

Theme	KPI no	Main Indicator	Availability
Mobility	1	Kilometers of high-capacity public transit system	+
	2	Light transit system	+
	3	Quality of pedestrian infrastructure	+
	4	Number of personal automobiles per capita	NI*
	5	Use of non-car transport	+
	6	Access to public transport	+
	7	Quality of public transport	+
	8	Improved access to vehicle sharing solutions	NI
	9	(Inter-) national accessibility	NI
	10	Extending the bike route network	+
	11	Access to public amenities	+
	12	Clean-Energy Transport	NI
	13	Access to commercial amenities	+
	14	Size of non-car transport network	+
	15	Green transport promotion	+
	16	Congestion reduction policies	+
	17	Sustainable, innovative, and safe transport systems	+
	18	Transportation demand management	+
	19	Inclusive Access	-

** NI: No Information.*

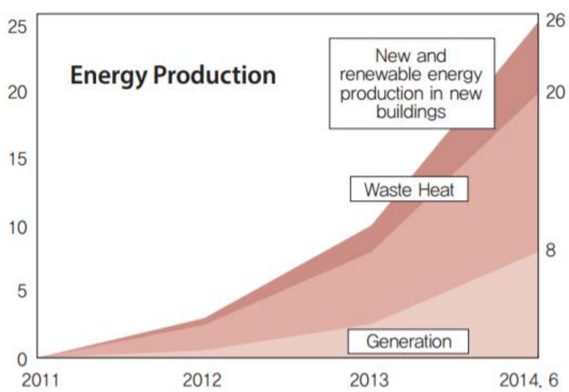
Figure 4. 11. An aerial image taken before and after the transportation limitation in Yonsei-ro. (Chua, 2016).

Regarding clean energy usage in transportation system, Seoul's policy is development of eco-friendly transportation vehicles. According to SMG (2014), some of the busses in public transportation system was replaced with either Compressed Natural Gas (CNG) busses, or electricity busses to reduce congestion rates. As of 2014, there are 7,460 CNG type city busses, 1,024 CNG type Meuel busses, that tours residential parts of Seoul, and 465 electrical busses (Seoul Metropolitan Government, 2014). That is why, the city is fulfilling the requirements for 16th KPI: Congestion Reduction Policies.

iii. Resources

According to SMG (2016), there are several renewable energy sources, and energy policies of city to obtain clean energy with reduction of resource consumption to achieve better environmental performance. Regarding the harm of Fukushima nuclear accident did in 2011, SMG made an action plan to reduce the nuclear energy dependency and increase the ratio of renewable energy. In 2011, 95% of the renewable energy of the city is obtained from waste generation resulted with biogas production, while only 2% of the energy is generated from solar energy – i.e. solar thermal energy or PV panels- that means the role of "new and renewable energy" is quite low. In 2012, the city initiated "Comprehensive Plan for One Less Nuclear Power Plant", which includes six development areas; "Expansion of new and renewable energy production; building retrofit program (BRP); establishment of environmentally-friendly, high-efficient transportation system; job creation in the energy industry; shift to a low-energy, urban spatial structure, and; creation of a civic culture promoting energy conservation." (Seoul Metropolitan Government, 2016). Till 2014, the city has gained an extensive progress in renewable energy generation from newly constructed buildings and waste generation. The amount of power generation of the city is equivalent to 57,403 tons of oil (TOE), and waste heat recovery is 119,218 TOE in 2014 (Figure 4.12). In this way, the city is fulfilling the requirements for 3rd KPI: Increase in Local Renewable Energy Production, 11th KPI: Infrastructure Energy Efficiency, and 12th KPI: Increase in % of Energy Produced from Renewable Sources.

The results of this project showed that total reduction of oil consumption and mentioned increase in renewable energy production provides reduction of 7.33 million tons GHG; thus fulfilling the requirements for 1st KPI: CO2 emission reduction, 2nd KPI: Decreased emission of NOx, and 3rd KPI: Decreased emission of Particulate Matter PM2,5 in Pollution theme. Furthermore, according SMG (2016), with the efficient use of energy regarding "One Less Nuclear Power Plant" project, 352,098 TOE through the energy consumption in new buildings; 192,304 TOE through BRP transportation system; 201,252 TOE through LED replacement, and; 123,370 TOE through environmentally friendly transportation (Seoul Metropolitan Government, 2016). In total, 869,024 TOE energy was recorded according to SMG (2016); thus, the city is fulfilling the requirements for 2nd KPI: Total Residential Electrical Usage, 4th KPI: Reduction in Annual Final Energy Consumption, 5th KPI: Reduction in Lifecycle Energy Use, 8th KPI: Increased Efficiency in Resource Consumption, 10th KPI: Optimizing Building Energy Performance Usage.



(Unit : TOE)

Energy Production	259,533
Power Generation (PV panel, hydrogen fuel cell, etc.)	57,403
Waste Heat Recovery (wastewater, incineration), Geothermal, Regenerative Power	119,218
Environmental Impact Assessment	82,912

Figure 4. 12. Energy production of Seoul depending on different categories. (Seoul Metropolitan Government, 2016)

According to Won & Ahn (2009), The Korea District Heating Corporation is the biggest company in Seoul that provides district heating service for the citizens. As of 2008, the company was providing heating and cooling service for heating and cooling to 1,028,574 residential buildings, 1,853 public and commercial buildings in a 1,433 km distribution network (Won & Ahn, 2009).Thus the city is fulfilling the requirements for 6th KPI: District Heating and Cooling.

It is a quite well-known information that hierarchy of waste separation consists of 4 steps. Treatment and disposal, energy recovery, recycling/ composting, and source reduction/reuse from least preferred to most preferred (Lee & Paik, 2011). The authors mentioned that initiation of decomposition of waste is the second important step in this hierarchical order. In 1995, government set a project called “volume based fee system (unit pricing system)” regarding waste separation in Korea, which neglects the fee for the separated waste of household, into recyclable components, such as, paper, glass, plastic, etc. (Lee & Paik, 2011; Yoo, 2015).

Waste disposal bags in Soul are in various volumes; such as 2, 3, 5, 10, 20, 30, 50, 75, and 100 liters, and respective fees with size (Yoo, 2015). According to Yoo (2015), behavior of the citizens towards waste and recycle process was changed, also with waste generation amount of the city, depending on the policy of government. In this way, the city is fulfilling the requirements for 24th KPI: Share of Recyclable Materials, and 27th KPI: Waste Recycling, and 26th KPI: Reduction in the Solid Waste. Moreover, the Reuse Plaza is aimed at promotion of reuse in Seoul, including the facilities of Recycling and Reuse Facility, Recycling Workshop, Recycling Museum, Bank of Recyclable Materials, Recycled Product Mall, and Space for Citizen Participation (Seoul Metropolitan Government, 2015).

Involvement of citizens in reuse process, with the help of workshops, touristic visits, and retail activities are the important potentials of this project regarding social sustainability. A perspective of the center is represented in Figure 4.13. According to Seoul Metropolitan Government (2015), usage of recycled construction materials and the building uses renewable energy sources were planned in the construction of the center. In this way, the city is fulfilling the requirements for 28th KPI: Recycled and Reused infrastructure, 22nd KPI: Share of recycled input materials, and 24th KPI: Share of recyclable materials. However, the facility has not started to run yet.

Table 4. 11. Assessment of Seoul for Resources theme.

Theme	Sub-Theme	KPI no	Main Indicator	Availability
Resources	energy	1	Percentage of city population with authorized electric service	NI*
		2	Total residential electrical use	+
		3	Increase in local **renewable energy** production	+
		4	Reduction in annual final energy consumption	+
		5	Reduction in lifecycle energy use	+
		6	District heating and cooling	+
		7	Solar orientation	NI
		8	Increased Efficiency in Resource consumption	+
		9	Reduction in embodied energy of products and services used in the product	NI
		10	Optimizing Building Energy Performance	+
		11	Infrastructure Energy Efficiency	+
		12	Increase in % of energy produced from the renewable sources	+
	water	13	Reduction in water consumption	NI
		14	Increase in water reused	NI
		15	Self-sufficiency - Water	NI
		16	Percentage of city population with potable water supply service	+
		17	Domestic water consumption per capita	NI
		18	Percentage of City Population with Sustainable Access to an Improved Water Source	NI
		19	Grey water use and rainwater harvesting	NI
	materials	20	Low impact Materials	NI
		21	Life Cycle Assessment	NI
		22	Share of Recycled Input Materials	+
		23	Share of Renewable Materials	NI
		24	Share of Recyclable Materials	+
		25	Municipal area Waste Production	+
		26	Reduction in the Solid Waste	+
		27	Waste Recycling	+
		28	Recycled and Reused Infrastructure	+

** NI: No Information.*

Figure 4. 13. A perspective of Reuse Center in Seoul.(Retrieved in 03.09.2017, from https://www.e-architect.co.uk/korea/seoul-recycle-plaza)

iv. Pollution

Measures of SMG related with greenhouse gasses are mentioned in Resources theme and evaluated positively in the table. Regarding light pollution, the problem was mentioned in the research of Cha, et al. (2014). The research is conducted on four different cities in Korea, including Seoul, and the results of the measurement show that light pollution is a common problem in Seoul (Cha, et al., 2014). Regarding all the subjected cities, light level of the building surfaces is above the limits. According to Cha, et al. (2014), the reason is the type of luminaires in public open spaces that are generally cutoff type. In cutoff type luminaries lightbulb part is fully open, in this way, unnecessary parts above eye level is illuminated, and it cause light pollution in atmosphere.

Regarding the light pollution in Seoul, government enacted “Act on the Prevention of Light Pollution by Artificial Lighting” in 2012. Within the scope of this act, several measures were taken into consideration by SMG. The first one is replacement of light bulbs in public roads with LED ones, to promote smart lighting, and enhance the better control of fixtures. In a ten year period –between 2011 and 2020-, the government aims at replacement of all light bulbs in roadways to reduce light pollution, and enhance energy efficiency (Seoul Metropolitan Government, 2017). In this way, the city is fulfilling the requirements for 5th KPI: Light Pollution Reduction.

According to SMG (2015b), 76.8% of the noise complaints are related with construction sites in Seoul. Between the years of 2009 to 2013, the complaints were almost doubled, that is why, and the government was taken the issue seriously. In 2011, the government take into action, and get some precautions in noise pollution reduction. Firstly, monitoring devices were attached to measure the level of noise in some of the large scale construction sites. Secondly, restrictions were imposed to reduce noise emergence in construction sites. For the projects smaller than 1000 m^2 GFA, it is obliged to install aluminum or polypropylene soundproof wall in the boundaries of site, and for the projects larger than 1000 m^2 GFA, it must be sheath plastic steel constructed in the periphery of site. Additionally, all the construction sites that includes drilling and blasting work items, that cause heavy sounds, have to install double layers of soundproof wall (Seoul Metropolitan Government, 2015). Considering the regulation, Seoul is fulfilling the requirements for 4th KPI: Noise Pollution Reduction.

Table 4. 12. Assessment of Seoul for Pollution theme.

Theme	KPI no	Main Indicator	Availability
Pollution	1	**CO2 emission** reduction	+
	2	Decreased emission of **NOx**	+
	3	Decreased emission of **Particulate Matter** PM2,5	+
	4	N**oise pollution** reduction	+
	5	Light Pollution reduction	+

4.4. The Case of Turkey

Regarding smartization process of Turkish cases, there are 25 different cities, mentioned within the scope of Smart City projects in literature, and some of them are in the beginning phases. The list of Smart Cities in Turkey is mentioned in Turkey Smart City Assessment Report (2016) is given in Figure 4.14. İstanbul, Eskişehir and İzmir are three examples that has fair amount of data on literature, and they are explained in this section. (Turkey Smart City Assessment Report, 2016).

Adana	Erzurum	Konya	Şanlıurfa
Ankara	Eskişehir	Malatya	Tekirdağ
Antalya	Gaziantep	Manisa	Trabzon
Aydın	Istanbul	Mardin	Van
Balıkesir	Izmir	Mersin	
Bursa	Kahramanmaraş	Muğla	
Denizli	Kocaeli	Sakarya	

Figure 4. 14. The list of Smart Cities in Turkey. (Turkey Smart City Assessment Report,2016).

İstanbul

Istanbul Metropolitan Municipality was received The U.S. Trade & Development Agency (USTDA) grant, for the improvement of cloud service and development of IT solutions of the municipality regarding the aggregation of data and from databases and related inputs, with the help of Geographic Information System (GIS). One of the smart mobility applications in İstanbul is Pedestrian Electronic Detection System of Isbak is designed for reduction in congestion rates of public transportation and prevent the delay rates of public transportation in crossroads. The other application is a parking automation system designed by Belbim Company, and within the scope of this project, the company aims to create a sustainable bicycle sharing system in future (Smart Cities in Turkey, n.d.).

There are various applications in İstanbul that are related with signalization systems. Beşiktaş Municipality has several smart city strategies which are mentioned in the "Akıllı Şehirler" database. First one is aimed at creation of a citizen oriented city. It includes collection of the problem of citizens in a shared medium. Complaints are forwarded to relevant bodies. Secondly, Social Alarm and Welfare System, which aimed at providing help in the case of emergency, targets elderly or disabled citizens. Within the scope of "Welfare Service", municipality provides in-place services regarding citizen's houses, such as "practical house arrangements", "in-place hair dresser service", and "In-place hygiene service". With the help of installed devices in houses, easy communication with elderly citizens is achieved. (http://www.akillisehirler.org/besiktas-belediyesi/).

BRT system which was also mentioned in Curitiba and Seoul cases has also been employed in İstanbul, since 2007. The system named as "Metrobüs", referring the combination of subway and bus system (http://metrobus.iett.istanbul/tr/metrobus/pages/metrobus-tarihce/222).

ISBAK (Istanbul IT and Smart City Technologies Inc.) is the institution that is responsible for the transportation related technologies of the smartization process in İstanbul. Alyürük who is the general manager of group mentioned Smart City appliances and future focuses of the ISBAK in an interview (Alyürük, 2017). Within the scope of this project, 2,159 "remote control and intelligent signaling systems", nearly 1,000 traffic cameras, 486 radar sensors for the measurement of traffic, 413 Bluetooth sensors for the calculation of travel time were provided to control the traffic in an efficient manner (Alyürük, 2017). Collected data transmitted into the digital medium.

Kadıköy municipality has taken into action to create environmental awareness, and published its sustainable energy action plan (Kadiköy Belediyesi Sürdürülebilir Enerji

Eylem Plani, n.d.). Within the scope of this plan, there are several sustainable measurements that the municipality was taken into action, including calculation of carbon footprint and emission of GHGs in municipal buildings, public transportation vehicles of municipality, street lighting, and other areas in the responsibility of municipality.

According to Kadıköy municipality, there is 1,310,180 m2 green area in Kadıköy within the responsibility of regional or metropolitan municipality (Kadiköy Belediyesi Sürdürülebilir Enerji Eylem Plani, n.d.). According to the data of Turkish Statistical Institute (TUIK), the population of Kadıköy is recorded 452,000 in 2016, and the region covers approximately 25,2 km2 (Kadiköy Belediyesi Sürdürülebilir Enerji Eylem Plani, n.d.). In this way, population density can be calculated as 17,936 persons for each km^2, and average green space ratio per inhabitant is 2,60 m^2 nearly.

Waste Coordination Center is one of the services that Kadıköy municipality offers with respect to energy action plan. The center organizes waste collection subcontractors, and several recyclable materials are collected, such as paper, glass, residual oil, dead batteries, etc. Additionally, there is also a facility that serves in electrical electronical material recycle. In order to reduce municipal area waste production, usage of plastic bags was restricted in 2010. To promote this act, citizens were informed, and environmentally friendly bags were distributed (Kadiköy Belediyesi Sürdürülebilir Enerji Eylem Plani, n.d.).

Built environment is the item that has major role in the carbon footprint in Kadıköy. That is why, municipality take into action for the reduction of energy consumption. It was mentioned in the energy action plan of municipality that regarding overall energy consumption of municipal service building of Kadıköy, 30% consisted of lighting. In this way, inefficient lighting fixtures in the building was replaced with LED fixtures. As a result, 59 tons of carbon was eliminated in annual carbon footprint layout. Additionally, reparation or removal of necessary fan-coils was done to increase efficiency of heating and cooling system, and Photovoltaic Panels was added to municipal building to provide hot water. In 2013, 5 new waste collection vehicles were renewed with electrical ones and reduction of 27 tons of carbon was calculated in annual basis as it was mentioned in Energy Action Plan (Kadiköy Belediyesi Sürdürülebilir Enerji Eylem Plani, n.d.).

Eskişehir

Eskişehir and its Tepebaşı district is an important example in terms of smartization in Turkey. The population of Tepebaşı is 314,599 (Garcia-Fuantes & Torre, 2017), which is nearly the 40% of the total population in Eskişehir (http://www.remourban.eu/Cities/Lighthouse-Cities/Tepebasi/Tepebasi-District.kl). Tepebaşı district is acclaimed as one of the "Lighthouse Projects" of Regeneration Model for Accelerating the Smart Urban Transformation (REMOURBAN). According to Garcia-Fuantes and Torre (2017), energy efficiency and climate targets of Tepebaşı municipality aims at 79% reduction in CO_2 emission rate and 85% reduction in energy consumption.

Yaşamköyü district in Tepebaşı municipality contains a mass housing project that is handled by governmental housing agency named as TOKİ. The project was built in 2007, the same year that Energy Efficiency law was enacted. Building stock of the project has low performance regarding energy efficiency characteristics; and thus, a transformation project was initiated in the Yaşamköyü district. The district includes 57 dwellings settled in 9,110 m^2 built area with 300 inhabitants. Within the scope of REMOURBAN project, Yaşamköyü has been identified as a demonstration site, and a retrofitting project was initiated. A district heating/cooling system that uses biomass as energy source and roof Photovoltaic panels were constructed in the district (http://www.remourban.eu/Cities/Lighthouse-Cities/Tepebasi/Tepebasi-District.kl).

According to Garcia-Fuantes and Torre (2017), there are several other technical and non-technical actions in Eskişehir Tepebaşı district to increase smartness and sustainability. Firstly, a monitoring system was constructed in district scale to observe

CO_2 emission and energy consumption, and the system has the functions of automatic control, occupancy control, and comfort controllers. Secondly, regarding transportation policy of the city, 50 e-bikes, 4 e-Buses & minibuses, and 7 Electric and Hybrid Vehicles for congestion reduction in traffic, also with 15 charging stations for bikes and 2 charging stations for electric vehicles. Lastly, smart phone apps were designed to enhance bike rental system, with, availability, location, information, and social media subscription functions; and Smart City monitoring portal to inform inhabitants (Garcia-Fuantes & Torre, 2017).

İzmir

Some of the smartization treatments of Izmir Metropolitan Municipality are mentioned in the website of Akıllı Şehirler (http://www.akillisehirler.org/izmir-belediyesi/) in 2016. Smart city studies of the İzmir is explained in several examples.

In Smart City solutions, İzmir is claimed to be the more developed in Intelligent Transport Systems (ITS) comparing with other cities in Turkey. Digital density maps of traffic for both passengers and drivers, traffic lights that provides audial guidance for disabled people, and a measurement system to keep the record of lights, speed or parking are the examples of smart mobility examples in İzmir (Smart Cities in Turkey, n.d.).

Supervisory Control and Data Acquisition (SCADA) is a system that determines water losses or system failures. It is used by relevant water authorization bodies in water distribution process in İzmir and several other large scale metropolitan cities in Turkey (Smart Cities in Turkey, n.d.).

Within the scope of Smart City project, several projects was initiated in İzmir, which are mostly related with digital tracking systems, and database creation or enhancement. Firstly, “Smart address” is transferring the address information of the neighborhoods, including building numberings, parcel lines, middle lines of roads, etc. in order to provide a updated and real time data. The service is the infrastructure of some others, such as 2D or 3D city guide, or smart land use that offers current condition and necessary data of lot. (http://www.akillisehirler.org/izmir-belediyesi/)

4.5. The Case of Middle East Technical University (METU)

The campus of METU is a self-contained district of Ankara, founded in 1956, and currently, provides education for approximately 27,000 students. The settlement is located between Eskişehir Road, 100. Yıl/Balgat district, and Bilkent İhsan Doğramacı University campus, where can be considered as a centralized part of Ankara in the present condition. The campus covers 4,500 hectares (45 km^2) area, 3,043 (nearly 30 km^2) hectares of which is a forest. METU campus has Lake Eymir, where is 20 km away from the city center. The campus provides accommodation for 7,000 students (http://www.metu.edu.tr/history). The density in the built environment of campus is 233 person per km^2, which is fulfilling the requirements of 17^{th} KPI: Density in Urban Environment theme. The campus is one of the most vegetated/green space of Ankara, where there are numerous kinds of living creatures and dense flora. Tree planting festivals were arranged with the contributions of all students, teachers and citizens who were members of the tree-planting club, at the time that METU was established. It is a very important event regarding the forestation of a formerly non-cultivated, arid land. The campus received Aga Khan Reward in 1995 (Koç, 2014). Moreover, Faculty of Architecture in METU has recently received Getty grant for the conservation of the building (http://www.getty.edu/foundation/initiatives/current/keeping_it_modern/grants_awarded_2017.html).

It has to be emphasized that METU campus is not entirely open to public access and participation, yet it can be considered as an urban area. For example, it not open to free access by citizens who have no relationship with university. However, it is a defined settlement, has many planning potentials with qualified space characteristics and a controversial district in Ankara.

In terms of university campuses in Turkey, METU campus has a distinguished space indeed. “Sustainable campus” features of METU was analyzed and compared with prominent sustainable campuses around world in the master thesis of Koç (2014).

a) Urban Environment

The planning model of METU contains a central building island that is closed to vehicular traffic. A linear, open air, public circulation element called “alley” defines the island. Various educational functions was aligned around the alley, where it begins with Faculty of Economic and Administrative Sciences, and ends with Department of Chemical Engineering and Civil Engineering. It is located at the central part of the campus which is shown in Figure 4.11. It was designed only for pedestrian walk, and vehicular traffic moves around the island. Consequently, alley is the island that gathers the departments and presents a pleasant environment, including short distances that allows walking and a mix of uses in the neighborhood. The direction of alley is on north south axis, and longer facades of the educational buildings are also faced to east and west.

The campus has planned to provide facilities in a neighborhood, including housing, commercial facilities, bookstore, banking services of five different companies, sports facilities in three different location, a stadium with 13,000 person capacity, “Technopark” for the companies aiming research and development, a healthcare facility, and a childcare facility for employees, besides education potential. Figure 4.17. represents the different facilities that are located at the central part of the campus, including food services, cafeterias, worship places etc.; hence fulfilling the requirements of 11th KPI: Access to public amenities, and 13th KPI: Access to commercial amenities in Mobility theme. Masterplan of the campus allows pedestrian activity depending on the development in a compact manner; thus fulfilling the requirements for 18th KPI: Compact Development, 19th KPI: Connected and Open community, 20th KPI: Mixed use neighborhoods. In this manner, ground floor usage is promoted, and urban design offers public recreational spaces for inhabitants, while fulfilling the requirements for the 12th KPI: Increased use of ground floors, 13th KPI: Increased access to urban public space. Pedestrian oriented urban design of the campus is fulfilling the requirements for 3rd KPI: Quality of pedestrian infrastructure of Mobility theme.

There is a former wetland located in the western part of the campus. The location of it is indicated in Figure 4.15. There is a slight level difference between the two main roads, the axis named as 2 is slightly higher than number 1. However, the wetland was drained years ago. The forestation of the region done with populous trees. As a result, the district does not pose danger anymore.

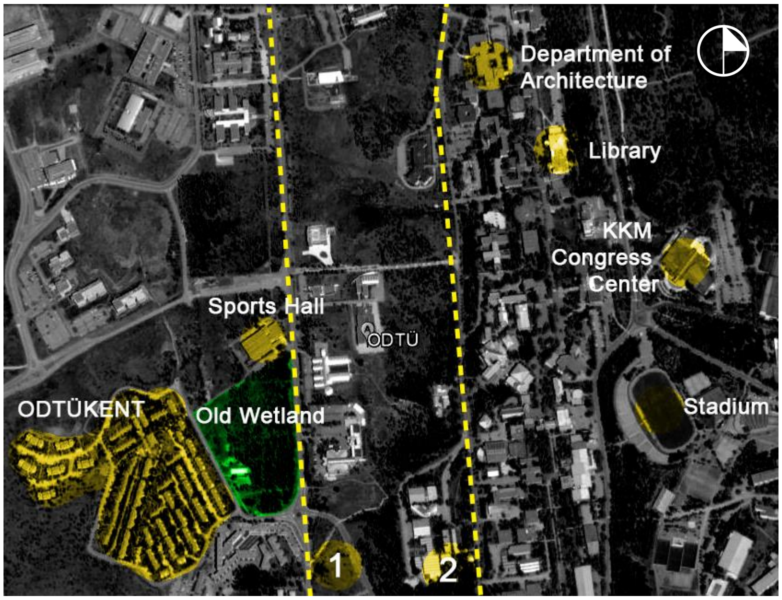


Figure 4. 15. Location of old wetland on METU campus. Base maps are taken from Google Earth.

Excluding built environment, approximately 3043 hectares of area has no settlement. Nearly half of the space was vegetated, with mentioned contributions of METU students, and academics. Vegetation of the campus consists mostly of native species, such as pinus nigra-black pine, which is the most suitable type of tree in middle

Anatolian steppe, horse chestnut trees, populous, etc. Furthermore, there is a conscious on protection of natural habitat in campus. There are 140 different bird and various animal species living in campus forest. Additionally, there are student clubs related with the protection of natural life. thus fulfilling the requirements for the 15th KPI: Landscape, 16th KPI: Biodiversity and interlinking habitats. Figure 4.16. shows the tree-lined streets; fulfilling the requirements for the 11th KPI: Access to green space, 14th KPI: Tree-lined and shaded street-scapes.

Figure 4. 16. Tree shaded roads of METU.

In the Library building, there is an exhibition hall. Throughout the educational semesters, it usually has a temporary display and it is open to public participation. Additionally, there are temporary exhibitions in the Kemal Kurdaş Congress Hall, and Department of Architecture (23rd KPI: Art in public space).

The campus is a purposefully designed spaces for many facility that inhabitants need, and procurement of required space characteristic integrated in this development. Regarding human-scale, communal spaces, and many other successful design characteristic, the campus has inevitably sense of place; thus fulfilling the requirements for the 7th KPI: Sense of Place, and 22th KPI: Development layout and flexible use.

Recently, lack of Universal Design principles of campus have been regarded as an obstacle in campus, and there are efforts on the positive transformation of campus mostly from the accessibility point of view. Entrances of several buildings was renovated, ramps and necessary elements were added in singular buildings.

Figure 4. 17. Diverse usage functions at campus map. Base maps are taken from Google Earth.

METU campus offers various residential opportunities for inhabitants. At first, in total 7,000 person capacity dormitories are used by the undergraduate and graduate students. There are variety of dormitory types, either 4-bed mixed dormitory room, or single studio room. There is also a guest house for research assistants. The campus offers lodging for academic staff, namely ODTÜKENT housing, and fulfills the requirements for the 24th KPI: Diversity of Housing, and 25th KPI: Housing Provision.

Among all the campus buildings of METU, there are very few green building initiatives. There is no guide for new construction or a green building regulation that is adopted by university. Most of the department buildings were constructed during the construction of campus itself, during 1950s. In a recent period of time, most of the research centers and TECHNOPARK buildings were constructed. The only campus buildings have environmental sensitivity is Ayaşlı Research Center, but the building has not been certified yet.

Table 4. 13. Assessment of METU for Urban Environment theme.

Theme	Sub-theme	KPI no	Main Indicator	Availability
Urban Environment	Site	1	Climate Action plan	NI*
		2	Historic resource preservation and adaptive reuse	+
		3	Minimized Site Disturbance	NI
		4	Flood risk assessment & management	NI
		5	Ecology Strategy	NI
		6	Connection to existing cultural heritage	+
		7	Sense of Place	+
		8	Brownfield remediation	-
		9	Agricultural Land Conservation	-
		10	Local food production	-
	Landscape	11	Access to green space	+
		12	Increased use of ground floors	+
		13	Increased access to urban public space	+
		14	Tree-lined and shaded street-scapes	+
		15	Landscape	+
		16	Biodiversity and interlinking habitats	+
		17	Density	+
	Urban Pattern	18	Compact Development	+
		19	Connected and Open community	+
		20	Mixed use neighborhoods	+
		21	Visibility and Universal Design	-
		22	Development layout and flexible use	+
		23	Art in public space	+
	Building	24	Diversity of Housing	+
		25	Housing Provision	+
		26	Smart Sustainable Buildings	-
		27	Building Reuse	-

** NI: No Information.*

As Akman (2016) cited in her thesis, during the excavation of the construction of the campus, there were some archeological remainings found from antique settlements in

Ahlatlıbel, Koçumbeli, and Yalıncak. That is why, a simultaneous survey work was started between the years of 1962-1968. At the end of the survey, findings were started to be exhibited in a museum. Currently, it is still in use, and artifacts that are belong to Phrygian times are presented (http://tacdam.metu.edu.tr/museum). In this way, the campus has a sense in historic resource preservation, and fulfilling the requirements for 2^{nd} KPI: Historic resource preservation and adaptive reuse, and 6^{th} KPI: Connection to existing cultural heritage.

Construction of Ayaşlı Research Center was completed in 2012. The architectural firm that is responsible for the design of the building is Çinici Architects, and partially Alican Demirden Architecture (AD Architecture). Total area of the site is nearly 6,000 m^2, with 3,185 m^2 gross floor area of building and located near by the Department of Electrical Electronical Engineering (https://eee.metu.edu.tr/ayasli-research-center). The building designed as northern and southern sections, which contributes energy optimization. The most prominent sustainability measure of the building is Photovoltaic Panels, and the annual energy generation of the building was predicted during the design stages of project as 60,000 KWH (Metu Electrical and Electronic Engineering Department, Ayaslı Research Center, 2012). Additionally, with a grey water treatment system, collected rain water from the roof filtrated and used in sanitary reservoirs and irrigation.

b) Mobility

In the case of 132 - 411 bus line, there are 49 trips for that bus line (for weekday). Also there are 3 different dolmuş lines for various regions of Ankara. However, there is one important aspect about it. There is no specific time regulation for it, dolmuş departs when it gets enough passenger. That is why, total trip counts will be calculated approximately. First of the line is Kızılay line, which is the most frequent line of METU. The departure period of it is nearly 15 minutes between 6 a.m. - 6 p.m., and 30 minutes between 6 p.m.-11.30 p.m. In other words, there are 59 trips for Kızılay dolmuş line for weekdays. Second line is Ayrancı line. The departure period is nearly 20 minutes between 6 a.m. and 7.30 p.m. That means there are 40 trips for weekday. The third line is Ulus. The departure period is roughly 30 minutes between 6 a.m. and 8 p.m., which means 28 trips for weekday. In total, there are 176 weekday trips for all bus and dolmuş lines in METU. Considering the weekend trip condition, the same bus and dolmuş lines are valid. In the case of 132nd bus line, there are 31 trips for that bus. Kızılay dolmuş line period is 20 minutes between 7 a.m. and 12 p.m. In other words, there are 51 trips for weekend, approximately. Ayrancı line works between 7 a.m. and 7.30 p.m., the period is 30 minutes. That means there are nearly 25 trips for weekend. Ulus line works between 7 a.m. and 7 p.m. and the departure period is 40 minutes. There are 19 total trips in this case, for weekend. In total, there are 126 trips in METU. As a result, public transportation scheme of the campus is fulfilling the requirements of 1st KPI: Kilometers of high-capacity public transit system, 6th KPI: Access to public transport, and 7th KPI: Quality of public transport. Table 4.10. summarizes the trip amount of dolmuş, bus and metro.

Besides buses and dolmuş, there is a subway stop outside of the campus, close to A1 entrance. There is an offered light transit system in the campus, connecting the Eskişehir road, and KKM Cultural Congress Center, but it has not built. Bus, dolmuş, and metro stops of the campus is represented in Figure 4.18.

Table 4. 14. Weekly trip amount of dolmuş, bus and metro.

Name of the Line	**Trip Amount**	
	Weekdays	**Weekends**
Kızılay Dolmuş Line	59	51
Ayrancı Dolmuş Line	40	25
Ulus Doşmuş Line	28	19
132-411 Bus Line	49	31
Metro	147	126 (Saturday) 119 (Sunday)

Besides public transportation system of campus, there is the ring system circulates inside of the campus, in several alternative roads. First of the routes covers the central dormitory region with departments, and second route covers the ODTÜKENT housing region with departments. Other routes generally covers A1 entrance, There was a mobile app designed in recent years, and still in use. The application gives the exact location of the ring in a map; thus partially fulfilling the requirements of 17th KPI: Sustainable, innovative, and safe transport systems.

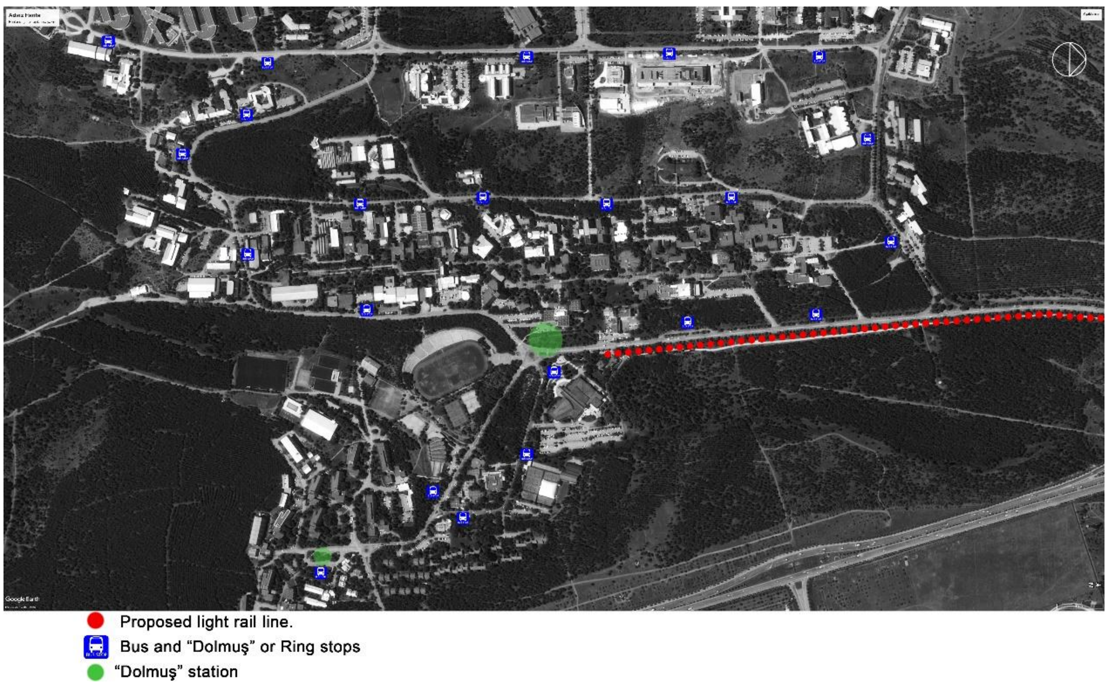


Figure 4. 18. Bus and dolmuş stops in METU.

The only measure of the METU campus regarding international accessibility is road signs in both Turkish and English; thus partially fulfilling the requirements of 9th KPI: (Inter-) National Accessibility. Disability Support Office is a unit of METU which is founded in 1998 (http://engelsiz.metu.edu.tr/en/about-dso). The unit is aimed at offering a better campus environment for the accessibility of all students, regarding academic, social, and professional sense (http://engelsiz.metu.edu.tr/en/missions-and-aims). The services of the unit for students with disabilities includes course partnership, note-taker support, unobstructed campus transportation with adapted vehicles or free taxi services, consultancy for departments with disabled students, etc. (http://engelsiz.metu.edu.tr/en/). However, there has still been insufficiencies in pedestrian access of disabled people. For example, there is an access to individual departments with car; however, the access of the person with mobile disability from a department to another is achieved only by car. The alley includes several level differences with stairs that blocks wheelchair access. That is why, the campus is partially fulfilling the requirements for 19th KPI: Inclusive Access.

Table 4. 15. Assessment of METU for Mobility theme.

Theme	KPI no	Main Indicator	Availability
Mobility	1	Kilometers of high-capacity public transit system	+
	2	Light transit system	-
	3	Quality of pedestrian infrastructure	+
	4	Number of personal automobiles per capita	NI*
	5	Use of non-car transport	NI
	6	Access to public transport	+
	7	Quality of public transport	+
	8	Improved access to vehicle sharing solutions	NI
	9	(Inter-) national accessibility	+
	10	Extending the bike route network	-
	11	Access to public amenities	+
	12	Clean-Energy Transport	-
	13	Access to commercial amenities	+
	14	Size of non-car transport network	NI
	15	Green transport promotion	NI
	16	Congestion reduction policies	-
	17	Sustainable, innovative, and safe transport systems	+
	18	Transportation demand management	NI
	19	Inclusive Access	+

** NI: No Information.*

Although the site of METU is mostly a suitable terrain for bicycle access, there is not a separate bicycle road in campus. The bicycle access is done in pedestrian paths. ID cards of university students, teachers, and administrative staff has an electronical chip. The library, and cafeteria payments are done only with the ID cards. Additionally, electronic stickers is provided for the car entrances to the campus for all vehicles, apart from visitors'. This is a good smartization example, considering the increasing speed in pedestrian and vehicular circulation in public spaces, minimizing the waiting periods.

c) Resources

Between the years of 1995-2015, there is project named "Recycle for Scholarship" in METU. According to the interview done with Himmet Gülcan, who is in charged in this project, the waste in campus is collected in various containers for recyclable materials. Gülcan mentioned that all of the recyclable materials were collected including paper, metal, glass, cardboards, waste oil etc. except the chemical wastes. Collected waste was stored in a collection center located in the southwestern part of campus, and transferred to Solid Waste Management facility in Ankara. Received income was provided students as scholarship; however, the project was cancelled in 2015 due to the legal constraints emerged. Since 2015, the waste in campus is collected by relevant bodies of Çankaya municipality. In this way, the campus is fulfilling the requirements for 24th Share of recyclable materials, 25th KPI: Municipal area Waste Production, and 27th KPI: Waste Recycling, with the service of municipality.

Photovoltaic panels attached on Ayaşlı Research Center is an example of renewable energy generation in the campus. According to the predictions during design procedure, the building will be generate 60,000 KWH energy annually (Metu Electrical and Electronic Engineering Department, Ayaslı Research Center, 2012). Additionally, there is an initiation of GUNAM (Güneş Enerjisi Araştırma ve Uygulama Merkezi) at the roof of Physics department. Thus, 3rd KPI: Increase in local renewable energy production, 12th KPI: Increase in % of energy produced from the renewable sources is partially fulfilled.

Table 4. 16. Assessment of METU for Resources theme.

Theme	Sub-Theme	KPI no	Main Indicator	Availability
Resources	energy	1	Percentage of city population with authorized electric service	+
		2	Total residential electrical use	NI*
		3	Increase in local **renewable energy** production	+
		4	Reduction in annual final energy consumption	NI
		5	Reduction in lifecycle energy use	NI
		6	District heating and cooling	+
		7	Solar orientation	-
		8	Increased Efficiency in Resource consumption	NI
		9	Reduction in embodied energy of products and services used in the product	NI
		10	Optimizing Building Energy Performance	NI
		11	Infrastructure Energy Efficiency	NI
		12	Increase in % of energy produced from the renewable sources	+
	water	13	Reduction in water consumption	NI
		14	Increase in water reused	NI
		15	Self-sufficiency - Water	NI
		16	Percentage of city population with potable water supply service	+
		17	Domestic water consumption per capita	NI
		18	Percentage of city population with sustainable access to an improved water source	NI
		19	Greywater use and rainwater harvesting	-
	materials	20	Low impact materials	NI
		21	Life Cycle Assessment	NI
		22	Share of recycled input materials	NI
		23	Share of renewable materials	NI
		24	Share of recyclable materials	+
		25	Municipal area Waste Production	+
		26	Reduction in the solid waste	NI
		27	Waste Recycling	+
		28	Recycled and Reused infrastructure	NI

** NI: No Information.*

District heating system provides the heating service of the most of the buildings in campus, except from ODTÜKENT lodging, Demiray dormitories, and several other building that were constructed in a closer period of time. The heating center is located at northwestern part of campus. In this way, the campus is fulfilling the requirements for 6th KPI: District heating and cooling. Furthermore, Koç (2014) mentioned in her thesis that recently, there are two measures were taken in order to provide efficient resource consumption. First one is refurbishment of HVAC systems in old buildings, by replacing old boilers with new energy efficient boilers. Second one is insulation of dormitory buildings with high efficient thermal insulation (Koç, 2014).

Every building in the campus has authorized electricity and potable water supply service. Thus, the campus is fulfilling the requirements for 1st KPI: Percentage of city population with authorized electric service, and 16th KPI: Percentage of city population with potable water supply service. The only rainwater harvesting strategy is planned in Ayaşlı Research Center. Collected rainwater is being used in irrigation or reservoirs.

d) Pollution

There is not a declared effort on the reduction of CO_2, NO_x, PM2,5, noise, or light by METU administrative committee.

Table 4. 17. Assessment of METU for Pollution theme.

Theme	KPI no	Main Indicator	Availability
Pollution	1	**CO2 emission** reduction	NI*
	2	Decreased emission of **NOx**	NI
	3	Decreased emission of **Particulate Matter** PM2,5	NI
	4	N**oise pollution** reduction	NI
	5	Light Pollution reduction	NI

** NI: No Information.*

CHAPTER 5

RESULTS & DISCUSSION

Through a detailed literature review, necessities for smartness and the KPIs that have been required for the smartization process of urban neighborhoods are determined. Significant cases from Europe, South America, and Asia are elaborately studied regarding the KPIs framework. In this chapter, evaluation of cases and indicators, with the recommendations for METU campus case is presented.

5.1. Evaluation of Cases

In the previous chapter, three cities are studied, namely Malmö, Curitiba, and Soul, which are the prominent examples of smartness. The articles, journals, conference proceedings, data sheets from web, and databases of relevant smart cities was researched in this process. According to the findings, the assessment of three city and METU campus is done regarding determined KPIs framework of this study. Results are presented in Table 5.1. It is important to indicate that all of the indicators are equally weighted. Additionally, each indicator is evaluated as "+", "-" or "NI" that means no information is found in literature about the indicator.

Table 5. 1. Assessment of Malmö, Curitiba, Seoul, and METU campus regarding KPIs framework.

		No	Key Performance Indicators	Malmö	Curitiba	Seoul	METU
Urban Environment	Site	1	Climate Action plan	+	+	+	NI *
		2	Historic resource preservation and adaptive reuse	NI	NI	+	+
		3	Minimized Site Disturbance	+	NI	NI	NI
		4	Flood risk assessment & management	+	NI	+	NI
		5	Ecology Strategy	+	+	+	NI
		6	Connection to existing cultural heritage	NI	NI	+	+
		7	Sense of Place	+	+	+	+
		8	Brownfield remediation	+	NI	+	-
		9	Agricultural Land Conservation	NI	+	NI	-
		10	Local food production	+	+	NI	-
	Landscape	11	Access to green space	+	+	+	+
		12	Increased use of ground floors	+	+	+	+
		13	Increased access to urban public space	+	+	+	+
		14	Tree-lined and shaded street-scapes	+	+	NI	+
		15	Landscape	+	+	+	+
		16	Biodiversity and interlinking habitats	+	+	+	+
		17	Density	+	+	+	+
	Urban Pattern	18	Compact Development	+	+	+	+
		19	Connected and Open community	+	+	+	+
		20	Mixed use neighborhoods	+	+	+	+
		21	Visibility and Universal Design	+	+	+	-
		22	Development layout and flexible use	+	+	NI	+
		23	Art in public space	+	NI	+	+
	Building	24	Diversity of Housing	+	+	+	+
		25	Housing Provision	+	+	+	+
		26	Smart Sustainable Buildings	+	NI	NI	-
		27	Building Reuse	+	NI	NI	-
Mobility		1	Kilometers of high-capacity public transit system	+	NI	+	+
		2	Light transit system	+	NI	+	-
		3	Quality of pedestrian infrastructure	+	+	+	+
		4	Number of personal automobiles per capita	+	+	NI	NI
		5	Use of non-car transport	+	+	+	NI
		6	Access to public transport	+	+	+	+
		7	Quality of public transport	+	+	+	+
		8	Improved access to vehicle sharing solutions	NI	NI	NI	NI
		9	(Inter-) national accessibility	NI	NI	NI	+
		10	Extending the bike route network	+	+	+	-
		11	Access to public amenities	+	+	+	+
		12	Clean-Energy Transport	+	+	NI	-
		13	Access to commercial amenities	+	+	+	+
		14	Size of non-car transport network	+	+	+	NI
		15	Green transport promotion	+	+	+	NI

Table 5.1. Continues.

		No	Key Performance Indicators	Malmö	Curitiba	Seoul	METU
		16	Congestion reduction policies	+	+	+	-
		17	Sustainable, innovative, and safe transport systems	+	+	+	+
		18	Transportation demand management	NI	+	+	NI
		19	Inclusive Access	+	+	-	+
Resources	energy	1	Percentage of city population with authorized electric service	NI	NI	NI	+
		2	Total residential electrical use	NI	NI	+	NI
		3	Increase in local **renewable energy** production	+	+	+	+
		4	Reduction in annual final energy consumption	+	+	+	NI
		5	Reduction in lifecycle energy use	NI	+	+	NI
		6	District heating and cooling	+	NI	+	+
		7	Solar orientation	NI	NI	NI	-
		8	Increased Efficiency in Resource consumption	NI	+	+	NI
		9	Reduction in embodied energy of products and services used in the product	NI	NI	NI	NI
		10	Optimizing Building Energy Performance	+	NI	+	NI
		11	Infrastructure Energy Efficiency	+	+	+	NI
		12	Increase in % of energy produced from the renewable sources	+	+	+	+
	water	13	Reduction in water consumption	+	+	NI	NI
		14	Increase in water reused	+	+	NI	NI
		15	Self-sufficiency - Water	NI	NI	NI	NI
		16	Percentage of city population with potable water supply service	NI	+	+	+
		17	Domestic water consumption per capita	+	+	NI	NI
		18	Percentage of city population with sustainable access to an improved water source	NI	NI	NI	NI
		19	Greywater use and rainwater harvesting	+	NI	NI	-
	materials	20	Low impact materials	+	NI	NI	NI
		21	Life Cycle Assessment	+	NI	NI	NI
		22	Share of recycled input materials	NI	+	+	NI
		23	Share of renewable materials	+	NI	NI	NI
		24	Share of recyclable materials	+	+	+	+
		25	Municipal area Waste Production	+	+	+	+
		26	Reduction in the solid waste	NI	+	+	NI
		27	Waste Recycling	+	+	+	+
		28	Recycled and Reused infrastructure	+	NI	+	NI
Pollution		1	**CO2 emission** reduction	+	+	+	NI
		2	Decreased emission of **NOx**	+	+	+	NI
		3	Decreased emission of **Particulate Matter** PM2,5	+	+	+	NI
		4	N**oise pollution** reduction	+	-	+	NI
		5	Light Pollution reduction	+	NI	+	NI

** NI: No Information.*

Table 5.1. consists of 4 different themes, which are Urban Environment, Mobility, Resources, and Pollution. It has 79 indicators in total. Regarding Urban Environment theme, Malmö is the most successful city, with 24 fulfilled indicators out of 27. Seoul

is in the second place with 20 indicators, and Curitiba is in the third place with 19 indicators. In Mobility theme, Malmö is the most successful city, with 16 fulfilled indicators out of 19. However, the results of Curitiba and Seoul is close to Malmö with 15 fulfilled KPIs. In Resources theme, Malmö is the most successful city, with 17 fulfilled indicators out of 28. Seoul has 16 fulfilled indicators while Curitiba has 15. In Pollution theme, Malmö and Seoul are leading cities that have 5 fulfilled indicators out of 5. Curitiba has 3 fulfilled indicators out of 5.

Malmö is the city that has dominancy in all four themes of this study. Even in some themes, the results are very close to each other, the city is in the lead. The city was mostly handled regarding Bo01 neighborhood which is a well-known example of ecological sustainability and transformation process of the district has covered las two decades. Urban environment is the theme that the city is most successful at, with 24 indicators out of 27. One of the reasons behind this is a deliberate attempt on design of a sustainable neighborhood. Furthermore, regarding smartization process, there is frequent model in some of the cities that is the focus on a specific district. It is a rather reasonable approach regarding the transformation of the complete, and Malmö is a valuable example of this model.

Importance of Curitiba in this study is not the fulfillment of many indicators. The city has perceived sustainability problem in 1970s, when the attempts of the government has also started on transportation problem. During nearly half century, BRT system was implemented, and deficiencies have been eliminated progressively. It was a very important achievement for Curitiba that nearly 40 countries, including Istanbul, were adopted the BRT system after the creation. The results of the BRT also affected energy consumption, carbon footprint, and pollution reduction of the city in a positive way, so that Curitiba is mentioned as “Greenest capital in Latin America”. Besides transportation oriented development, Curitiba is a prominent city regarding waste. It is an impressive rate for a city to achieve disposal of the waste 100%. Although official website of Curitiba Municipality presents so few sources about the city in English, there is fair amount of literature that presents smartness and sustainability of the city.

Furthermore, selection of Curitiba as a case is more convenient for study, regarding its similar context with Turkey, rather than North American cities.

The first point that should be mentioned about Seoul is online informative system of the city, namely Seoul Solution, and it is the most successful one among three of the cases. All subjects were divided to relevant headings, and if the city answers any sustainability measure, it can be easily found in the online platform. Even though this attitude aims at advertisement overmuch, it is an important issue to inform citizens about the sustainability necessities, and create the conscious. Even the rare KPIs of the framework, such as historical preservation and connection to cultural heritage, the city has gained a progress.

It should also be pointed out that urban development is closely related with monetary concerns in most of the countries. Economic development level can easily affect the investments in urban development and sustainability planning. Sweden is one of the countries that have high income level in world. Gross national income per capita in Sweden, Brazil, and Seoul are respectively; $50,000, $14,810, and $35,790 in 2016 (https://data.worldbank.org/indicator/NY.GNP.PCAP.PP.CD?year_high_desc=true). In this way, economic development of the country can be a factor in the achievement of sustainability.

5.2. Evaluation of Indicators

In Urban Environment theme, there are 27 indicators in total. Amon three case studies, the indicators that accomplished most are 1st KPI: Climate Action Plan, 5th KPI: Ecology Strategy, 7th KPI: Sense of Place, 11th KPI: Access to green space, 13th KPI: Increased access to urban public space, 15th KPI: Landscape, 16th KPI: Biodiversity and interlinking habitats, 17th KPI: Density, 18th KPI: Compact Development, 19th KPI: Connected and Open community, 20th KPI: Mixed use neighborhoods, and 21st KPI: Visibility and Universal Design. The least accomplished indicators are 2nd KPI:

Historic resource preservation and adaptive reuse, 3rd KPI: Minimized Site Disturbance, 6th KPI: Connection to existing cultural heritage, 26th KPI Smart Sustainable Buildings, and 27th KPI: Building Reuse.

In Mobility theme, there are 19 indicators in total. The indicators that accomplished most are 3rd KPI: Quality of pedestrian infrastructure, 6th KPI: Access to public transport, 7th KPI: Quality of public transport, 13th KPI: Access to commercial amenities, 17th KPI: Sustainable, innovative, and safe transport systems. The least accomplished indicators are 8th KPI: Improved access to vehicle sharing solutions, and 18th KPI: Transportation demand management. Additionally, Mobility is the theme that success rate is highest regarding three case studies. All of the cities have considerable achievements, innovations, and applications regarding the measures of mobility.

In Resources theme, there are 28 indicators in total. The indicators that accomplished most are 24th KPI: Share of recyclable materials, 25th KPI: Municipal area Waste Production, and 27th KPI: Waste Recycling. The least accomplished indicators are 2nd KPI: Total residential electrical use, 15th KPI: Self-sufficiency – Water, 18th KPI: Percentage of city population with sustainable access to an improved water source, 26th KPI: Reduction in the solid waste.

In Pollution theme, there are 5 indicators in total. The indicators that accomplished most are 1st KPI: CO2 emission reduction and 2nd KPI: Decreased emission of NOx. 3rd KPI: Decreased emission of Particulate Matter PM2,5, 4th KPI: Noise pollution reduction, and 5th KPI: Light Pollution reduction has lowest accomplishment rate.

It is important to emphasize that regarding these three cases and other important smart city examples around the world, the process has not begun with the smartness, which has emerged in last decade. Smartness is the later phase of the environmental awareness progress that is mentioned in literature review chapter. In this term, the development of the cities that have a background in sustainability initiations, it is easier to make a progress, especially in energy and infrastructure point of view.

5.3. Evaluation of Turkey and Recommendations

Smart City concept have been given weight in Turkey, and there are several initiations regarding this concept. However, all of the examples are in the beginning phases of smartization process. That is why, it is not reasonable to evaluate these cities based on KPIs framework of this study. Alternatively, smartness applications of two prominent cities in national context is mentioned to give an idea. The smartness initiations in Turkey are generally depending on findings in literature.

Regarding smartness applications in Turkey, there is a dominance in ICT based solutions, which is a pragmatic point for our country. Energy efficiency in built environment is a long term development and not a cost-effective solution. The results of an effective transportation hub reduce congestion rates and thus carbon footprint of the city, while renovations in built environment regarding resource consumption reduction is not considered as a cost-effective solution by the authorities. Moreover, ICT is the inseparable component of smartness in city domain. Although mentioned two topics are important in Smart Cities, certain measurements should also be planned in smartization process of cities in the case of Turkey. Firstly, climate action plan is critical in current condition of cities, and it should be handled by relevant professionals for each city. Secondly, monitoring is a fundamental component of smart cities. Smart meters should be attached to buildings. Furthermore, rainwater harvesting and grey water treatment strategies, waste reduction and recycling, and renewable energy generation initiations are recommended. In transportation, clean / green energy usage should be increased.

5.4. Evaluation of METU Case and Recommendations

METU campus has more than half century past, and it is not only a successful example of university campus, but also a significant example of a self-contained neighborhood. Presented architectural functions, togetherness of the functions, indoor & outdoor space creation, and coherency of user and space are several positive measures that

METU campus offers to inhabitants. Mentioned features of the campus are generally related with architectural design / urban design properties. It is mentioned relevant KPIs of Urban Environment theme of the framework. However, if we consider the environmental sustainability measures of created KPI framework of this study, there are lacking measures in METU campus. For example, monitoring is one of the fundamental indicators of smartization, as it is mentioned in literature. In a very basic sense, it is crucial to obtain the information of consumption and generation in buildings and urban environment, thus it will be possible to create a strategy depending on obtained results. Primary missing points of METU campus in KPI framework of this study is explained with relevant themes.

Urban environment is the theme that the amount of fulfilled KPIs are highest, in METU case. Among 27 KPIs of the theme, 17 is fulfilled. Regarding the future interventions to the campus area, following KPIs should be handle at first place. 26th KPI: Smart Sustainable Buildings is a significantly missing in the campus. There is only one building that has environmental conscious. In first place, smart building initiations with smart metering appliances, and building automation systems should be added, and energy efficiency should have priority in buildings. Second indicator that is recommended to be considered is 1st KPI: Climate Action Plan. There is a conscious on protection of environment in METU campus with respect to inhabitants. However, possible scenarios in future should be evaluated, and precautions should be taken. Last indicator that is missing at the campus is 10th KPI: Local Food Production. METU campus was settled on a wide area, and 30 km^2 were treated as green area. There are plenty of space that could be used as agricultural purposes, with the contributions of students.

Mobility is second theme of the KPIs framework of this study. There are 19 KPIs in this theme in total, and 9 of them is fulfilled by campus. The first indicator that is recommended to campus is 12th KPI: Clean-Energy Transport regarding public transportation facilities. There is a good example of the indicator in Malmö. Public busses using biogas, produced from the food wastes that are collected from houses, as a fuel. Additionally, congestion rates of the public transportation vehicles should be investigated, and necessary measures should be discussed. Secondly, 10^{th} KPI: Extending the bike route network is recommended to METU campus. Currently, bicycled passengers are using pedestrian roads (Alley) or vehicular roads but it is not a reasonable solution. The campus, where is a compact built island, is suitable with bicycle access. The proposal of the possible bicycle route, and a typical bike road section is represented in Figure 5.1., and Figure 5.2.

Resources is the third theme of the KPIs framework of this study, and it includes energy, water, and materials sub-themes. There are 28 KPIs in this theme in total, and 8 of them is fulfilled by campus. It is the theme that has second lowest score among 4 themes of the framework. The recommendations for this section are as follows. The most important missing point regarding energy related KPIs is absence of monitoring, and this is mentioned in Urban Environment theme. GUNAM is an initiation that works on the research and development of PV panels, and making a research on some of the buildings in campus but the amount of them is low. Recommended indicators within the scope of energy sub-theme are namely, 4th KPI: Reduction in annual energy consumption, 3rd KPI: Increase in local renewable energy production, and 10th KPI: Optimizing Building Energy Performance. Considering water consumption, there is neither a rainwater management strategy, nor a greywater treatment system. That is why, 13th KPI: Reduction in water consumption, and 19th KPI: Grey water use and rainwater harvesting is recommended. Lastly, 26th KPI: Reduction in the solid waste, 20th KPI: Low impact materials is recommended important indicators for METU campus.

Pollution is the fourth and last theme of the KPIs framework of this study. None of 5 KPIs is fulfilled in METU campus. The essential point is measurement of the levels of mentioned GHG, noise, and light levels, and the evaluation of thread level of these three.

Figure 5. 1. Typical bike road section offered in METU campus.

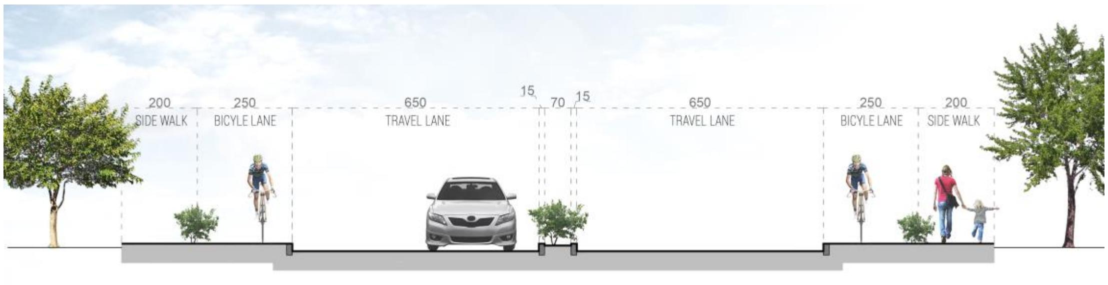


Figure 5. 2. Proposal of the possible routes of bicycle road in METU campus.

CHAPTER 6

CONCLUSION

In last half century, sustainability was emerged with the purpose of maintaining the sources, regarding ecological, social, and economical terms in a basic sense. Decreasing sources and raising awareness on the sustainable notion is the major reason in this term. In last decade, smartness was emerged regarding digitalization of society, with the purpose of efficiency in a sense. Hard and soft infrastructure in a smart city is basically fastens the flow, such as in the ID cards example. ID cards can be counted as a measure of smartness, pedestrian traffic can be increased by using them in public buildings, and no waiting time at entrances means time and energy consumption. That is why, smartness can be considered as an enhancement in sustainable development in digitalized society.

Within the scope of this study, definition and boundaries of smart and sustainable cities were researched. Through an extensive literature search, historical evaluation of the concept, background information on concept and necessary KPIs to become a smart city were determined. Gathered indicators were condensed in a framework. One of the limitations of this study is that some of the Smart City standards cannot be obtained because of copyright and funding limitations. There are very many categories related with smart cities, such as governance, health, people, etc. However, the themes that are related with built environment were gathered in the framework.

There are very many smart city examples around the world, and among them, 3 state-of-art smart cities were selected, and studied in depth, depending on the findings from literature and data sheets from internet, and assessed. According to the framework, Malmö is the city that has more indicators than Seoul and Curitiba. The limitation of this study is data availability. The cities were assessed depending on online information, and in some points, there can be missing or unavailable information online. METU campus, which is a non-smart settlement, is also assessed with determined KPIs, and necessary indicators was recommended for the smartization process of campus.

Although it is hard to evaluate the degree of smartness or sustainability with an assessment scheme, necessary smartization steps can be determined in the non-smart example. Additionally, comparison between cases have become possible.

One of the missing concepts in the smartization or creation of sustainable neighborhoods in Turkey is inadequacy of the holistic approach in urban scale decisions. Most of the current studies on smart cities in Turkey remain superficial. Most of the projects of the municipalities are related with creation of databases with public works, and ICT based solutions. However, in Turkey, pedestrian infrastructure and the decisions related with urban pattern are not in similar level comparing with studied cases around the world. Furthermore, it is a common tendency in Malmö, Curitiba, and Seoul that primary development of transportation / mobility systems regarding smart sustainable notions. In later phases, the achievement of a well-developed transportation systems resulted in energy and resource consumption reduction, carbon footprint and GHG emission reduction. That is why, mobility is a strategic theme that should be considered in the first phases of smart city projects in Turkey.

Middle East Technical University campus is an important self-contained district in Ankara. It can be a strategic neighborhood regarding smartization and creation of a self-sustainable island. Urban pattern and pedestrian oriented design decisions in masterplan are the measures that makes the campus a distinct example. It could be a reasonable strategy to select a specific district and focusing on the development of the area, rather than whole of the city. As mentioned before, this is a model that is the case of Malmö, Sweden, and several other examples around the world, and it can also be effective for the case of Turkey.

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APPENDIX I

Table A.1. Final Smart City KPIs framework, Urban Environment theme.

Theme	Category	No.	Main Indicator	Source	Subindicator	Type of Indicator	Unit
urban environment	Site	1	Climate Action plan	LEED, CITYkeys, BREEAM, ISO-Green, SC-Index, DGNB	Suggestion: For coastal towns: Increase or decrease in water level at sea.	Sustainable	Exist or not exist
		2	Historic resource preservation and adaptive reuse	LEED		Sustainable	
		3	Minimized Site Disturbance	LEED		Sustainable	
		4	Flood risk assessment & management	BREEAM, LEED		Sustainable	
		5	Ecology Strategy	BREEAM, DGNB		Sustainable	
		6	Connection to existing cultural heritage	CITYkeys	Aims at preservation of cultural heratige.	Sustainable	Likert
		7	Sense of Place	CITYkeys	Sense of Place.	Sustainable	Likert
		8	**Brownfield** remediation.	LEED, CITYkeys, ISO-Green	Brownfield remediation	Sustainable	% of km2
		9	Agricultural Land Conservation	LEED,DGNB		Sustainable	
		10	Local food production	LEED, CITYkeys, DGNB	Urban Gardens for citizens	Sustainable	
	Landscape	11	Access to green space	CITYkeys	Amount of green space in m2	Sustainable	hectares /100.000
				SC Index	Green Space per capita. (SC Index)	Sustainable	m2 of green areas in 100.000 m2
				STEEP	Green area per 100.000 population (STEEP)	Sustainable	
		12	Increased use of gound floors	CITYkeys, BREEAM	Ground floor usage	Sustainable	% in m2
		13	Increased access to urban public space	CITYkeys, LEED, BREEAM, DGNB	Public outdoor recreation space	Sustainable	m2/cap
		14	Tree-lined and shaded street-scapes	LEED		Sustainable	
		15	Landscape	BREEAM	Preparation of detailed landscape design with respect to usage of native species, water efficiency, and	Sustainable	

			Main Indicator	Source	Subindicator	Type of Indicator	Unit
					ecological strategy offered by an ecology clerk.		
		16	Biodiversity and interlinking habitats	DGNB		Sustainable	
		17	Density	SC Index	Population weighted density	Sustainable	
	urban pattern	18	**Compact Development**	LEED		Sustainable	
		19	**Connected and Open community**	LEED, BREEAM		Smart+ Sustainable	
		20	Mixed use neighborhoods	LEED, DGNB		Sustainable	
		21	Visibility and **Universal Design**	LEED, BREEAM, DGNB		Sustainable	
		22	Development layout and flexible use	DGNB		Sustainable	
		23	Art in public space	DGNB		Sustainable	
	Building	24	Diversity of Housing	CITYkeys	Diversity of Housing	Sustainable	Simpson Diversity Index
		25	Housing Provision	BREEAM		Sustainable	
		26	Smart Sustainable Buildings	SC Index	Sustainably certified buildings, BREEAM or LEED	Smart	%
				SC Index	**Smart homes**: % of commercial and industrial buildings with smart metres (SC Index).	Smart	%
				SC Index	**Smart homes**: % of commercial buildings with a buildig automation system (SC Index).	Smart	%
				SC Index	**Smart homes**: % of homes with smart meters	Smart	%
				ISO-Green	Energy efficient building initiatives	Smart	
		27	Building Reuse	LEED, BREEAM, DGNB		Sustainable	

Table A.2. Final Smart City KPIs framework, Mobility theme.

		Main Indicator	Source	Subindicator	Type of Indicator	Unit
mobility	1	Kilometres of **high-capacity** public **transit** system	ISO-smart, STEEP	Number of 2 wheel motorized vehicles	Smart	km / 100,00 ppl
	2	Kilometres of **light transit** system	ISO-smart	Commercial Air Connectivity (number of non-stop commercial air destinations)	Smart	
	3	Quality of pedestrian infrastructure	DGNB		Sustainable	
	4	**Number of personal automobiles per capita**	ISO-smart, STEEP,	Transportation fatalities	Sustainable	per 100.000
				Annual number of public transit trips	Sustainable	per capita ?
	5	Use of **non-car transpor**t	ISO-green		Smart	
	6	Access to public transport	CITYkeys, EU, BREEAM		Smart+ Sustainable	% of ppl
	7	Quality of public transport	CITYkeys, EU, DGNB		Smart+ Sustainable	
	8	Improved access to **vehicle sharing** solutions	CITYkeys	Access to vwhicle sharing solutions for city travel	Smart	# / 100,000
	9	(Inter-) national accessibility, *with respect to UD*	EU	International accessibility	Smart	
	10	Extending the **bike** route netwrok	CITYkeys, BREEAM, SC-Index, DGNB	Length of bike route network	Smart+ Sustainable	% in km
	11	Access to public amenities	CITYkeys	Access to public amenities	Smart	% of ppl
	12	**Clean-energy** Transport	SC Index	# of shared bicyles	Smart	# / per capita
			SC Index	# of shared vehicles	Smart	# / per capita
			SC Index	# of EV charging stations within the city	Smart	# / per capita
	13	Access to commercial amenities	CITYkeys	Access to commercial amenities	Smart	% of ppl
	14	Size of non-car transport network	ISO-green		Smart	
	15	Green transport promotion	ISO-green		Smart	
	16	Congestion reduction policies	ISO-green, BREEAM		Smart+ Sustainable	
	17	Sustainable, innovative, and safe transport systems	EU	Green mobility share	Smart	

		Main Indicator	Source	Subindicator	Type of Indicator	Unit
			EU	Traffic Safety	Smart	
			EU	Use of Economical Cars-	Smart	
	18	Transportation demand management	LEED, BREEAM		Sustainable	
	19	Inclusive Access	DGNB		Sustainable	

Table A.3. Final Smart City KPIs framework, Resources theme.

			Main Indicator	Source	Subindicator	Type of Indicator	Unit
Resources	energy	1	Percentage of city population with authorized electric service	ISO-Smart	Total electrical use	Smart	kWh/year
		2	Total residential electrical use	ISO-Smart	The average of electrical interruptios per customer per year	Smart	kWh/year
				ISO-Smart	Average length of electrical interruptions	Smart	in hours
		3	Increase in local **renewable energy** production	CITYkeys, BREEAM, DGNB,	Renewable energy gathered within the city	Smart+ Sustainable	% in MWh
		4	Reduction in annual final energy consumption	CITYkeys, BREEAM, DGNB	Annual final energy consumption	Smart+ Sustainable	mwh /cap/yr
		5	Reduction in lifecycle energy use	CITYkeys, DGNB		Smart+ Sustainable	% in kwh
		6	District heating and cooling	LEED, BREEAM		Sustainable	
		7	Solar orientation	LEED, BREEAM		Sustainable	
		8	Increased Efficiency in Resource consumption	CITYkeys, BREEAM	Domestic material consumption	Smart+ Sustainable	t/cap/year
		9	Reduction in embodied energy of products and services used in the product	CITYkeys, DGNB		Smart+ Sustainable	
		10	Optimizing Building Energy Performance	LEED	Optimize building energy performance	Sustainable	
		11	Infrastructure Energy Efficiency	LEED		Sustainable	

			Main Indicator	Source	Subindicator	Type of Indicator	Unit
		12	Increase in % of energy produced from the renewable sources	SC Index, ISO-Green		Smart	
	water	13	Reduction in water consumption	CITYkeys, BREEAM	-Water consumption -Water losses	Smart+ Sustainable	liters/cap/year % of m3
		14	Increase in water reused	CITYkeys, LEED, BREEAM, DGNB	Grey and rainwater use	Smart+ Sustainable	% of houses
		15	Self-sufficiency - Water	CITYkeys	Water exploitation index	Smart	% of m3
		16	Percentage of city population with potable water supply service	ISO-smart	Total water consumption	Smart	Lt/day
		17	Domestic water consumption per capita	ISO-smart	Percentage of water loss	Smart	
		18	Percentage of city population with sustainable access to an improved water source	LEED	Average annual hours of water service interruption	Sustainable	
		19	Greywater Use and Rainwater harvesting	BREEAM,		Sustainable	
	materials	20	Low impact materials	BREEAM	Promotion of usage of low impact materials that has higher grades in Green Guide to Specification.	Sustainable	
		21	Life Cycle Assessment	DGNB		Sustainable	
		22	Share of recycled input materials	CITYkeys		Smart	% in tonnes
		23	Share of renewable materials	CITYkeys		Smart	% in tonnes
		24	Share of recyclable materials	CITYkeys		Smart	% in tonnes
		25	Municipal area Waste Production	ISO-Green		Smart	
		26	Reduction in the solid waste	CITYkeys, ISO, ISO, LEED, DGNB	Municipal solid waste recycling rate	Smart+ Sustainable	tons/cap/yr % of tonnes
		27	Waste Recycling	ISO-Green, DGNB		Smart+ Sustainable	
		28	Recycled and Reused infrastructure	LEED, DGNB		Sustainable	

Table A.4. Final Smart City KPIs framework, Pollution theme.

		Main Indicator	Source	Subindicator	Type of Indicator	Unit
Pollution	1	**CO2 emission** reduction	CITYkeys, SC Index, ISO, BREEAM	CO2 emissions	Smart+ Sustainable	% in tones
				Reduction in lifecycle CO2 emissions	Sustainable	tones CO2/cap/year
	2	Decreased emission of **NOx**	CITYkeys, ISO-Smart	Nitrogen oxide emissions	Smart	g/cap
	3	Decreased emission of **Particulate Matter** PM2,5	CITYkeys, ISO-Smart	Fine particulate matter emissions	Smart	g/cap
				Air quality index	Sustainable	Index
	4	N**oise pollution** reduction	CITYkeys, LEED, BREEAM, DGNB	Noise pollution	Smart+ Sustainable	% of ppl
	5	Light Pollution reduction	BREEAM	Minimum lighting for the streets and high efficient appliances will be installed	Sustainable	

APPENDIX II

Table A.2. List of Smart Cities around the world.

	Name of the City	Continent
1	**Malmö**	Europe
2	Amsterdam	Europe
3	Rotterdam	Europe
4	Copenhagen	Europe
5	Plan IT Valley	Europe
6	Malta	Europe
7	Aarhus	Europe
8	Athens	Europe
9	Crete	Europe
10	Plovdiv	Europe
11	Varna	Europe
12	Palermo	Europe
13	Naples	Europe
14	Florence	Europe
15	Bologna	Europe
16	Seville	Europe
17	Valencia	Europe
18	Liverpool	Europe
19	Edinburgh	Europe
20	Stuttgart	Europe
21	Dresden	Europe
22	Leipzig	Europe
23	Frankfurt	Europe
24	London	Europe
25	Paris	Europe
26	Berlin	Europe
27	Zurich	Europe
28	Vienna	Europe
29	Geneva	Europe
30	Munich	Europe
31	Stockholm	Europe
32	Oslo	Europe
33	Madrid	Europe
34	Helsinki	Europe
35	Dublin	Europe
36	Hamburg	Europe
37	Barcelona	Europe

	Name of the City	Continent
38	Milan	Europe
39	Glasgow	Europe
40	Brussels	Europe
41	Prague	Europe
42	Rome	Europe
43	Linz	Europe
44	Basel	Europe
45	Lyon	Europe
46	Malaga	Europe
47	Lisbon	Europe
48	Tallinn	Europe
49	Warsaw	Europe
50	Manchester	Europe
51	Eindhoven	Europe
52	Cologne	Europe
53	Turin	Europe
54	Birmingham	Europe
55	Antwerp	Europe
56	Budapest	Europe
57	Nottingham	Europe
58	Ljubljana	Europe
59	Vilnius	Europe
60	Marseilles	Europe
61	Nice	Europe
62	Bilbao	Europe
63	Leeds	Europe
64	Bratislava	Europe
65	A Coruña	Europe
66	Lille	Europe
67	Riga	Europe
68	Zagreb	Europe
69	Gothenburg	Europe
70	Sofia	Europe
71	Wrocław	Europe
72	Duisburg	Europe
73	Porto	Europe
74	Istanbul	Europe
75	Bucharest	Europe
76	Kiev	Europe
77	Budapest	Europe
78	Minsk	Europe

	Name of the City	Continent
79	Sarajevo- Bosnia	Europe
80	Skopje	Europe
81	Helsinki	Europe
82	Kaunas	Europe
83	Bradford	Europe
84	Bristol	Europe
85	Cardiff	Europe
86	Leicester	Europe
87	Sheffield	Europe
88	Bydgoszcz	Europe
89	Gdanz	Europe
90	Katowice	Europe
91	Lodz	Europe
92	Poznan	Europe
93	Szczecin	Europe
94	Wroclaw	Europe
95	Bielefeld	Europe
96	Bochum	Europe
97	Bonn	Europe
98	Bremen	Europe
99	Dortmund	Europe
100	Dusseldorf	Europe
101	Essen	Europe
102	Hannover	Europe
103	Mannheim	Europe
104	Nurnberg	Europe
105	Wuppertal	Europe
106	‘S-Gravenhage	Europe
107	Liege	Europe
108	Aix-en-provence	Europe
109	Bordeaux	Europe
110	Grenoble	Europe
111	Montpellier	Europe
112	Nantes	Europe
113	Rennes	Europe
114	Saint-Etienne	Europe
115	Strasbourg	Europe
116	Toulon	Europe
117	Toulouse	Europe
118	Alicante	Europe
119	Cordoba	Europe

	Name of the City	Continent
120	Las Palmas	Europe
121	Palma de Mallorca	Europe
122	Valladolid	Europe
123	Zaragoza	Europe
124	Bari	Europe
125	Genova	Europe
126	Brno	Europe
127	Ostrava	Europe
128	Cluj-Napoca	Europe
129	Timisoara	Europe
130	Thessaloniki	Europe
1	Singapore	Asia
2	Songdo	Asia
3	**Seoul**	Asia
4	Masdar	Asia
5	Beijing	Asia
6	Tianjin	Asia
7	Shanghai	Asia
8	Yokohoma	Asia
9	Bengalore	Asia
10	Taipei	Asia
11	Astana	Asia
12	Kabul	Asia
13	Tokyo	Asia
14	Hong Kong	Asia
15	Abu Dhabi	Asia
16	Dubai	Asia
17	Osaka	Asia
18	Nagoya	Asia
19	Bangkok	Asia
20	Moscow	Asia
21	Kuala Lumpur	Asia
22	Busan	Asia
23	Guangzhou	Asia
24	St Petersburg	Asia
25	Daejeon	Asia
26	Tel Aviv	Asia
27	Jerusalem	Asia
28	Daegu	Asia
29	Haifa	Asia
30	Schenzhen	Asia

	Name of the City	Continent
31	Jeddah	Asia
32	Almaty	Asia
33	Tbilisi	Asia
34	Wuhan	Asia
35	Kuwait City	Asia
36	Suzhou	Asia
37	Doha	Asia
38	Riyadh	Asia
39	Manama	Asia
40	Kaohsiung	Asia
41	Baku	Asia
42	Taichung	Asia
43	Ho Chi Minh City	Asia
44	Ankara	Asia
45	Manila	Asia
46	Tainan	Asia
47	Novosibirsk	Asia
48	Bursa	Asia
49	Jakarta	Asia
50	Chongqing	Asia
51	Mumbai	Asia
52	Tehran	Asia
53	Shenyang	Asia
54	Tianjin	Asia
55	Harbin	Asia
56	Delhi	Asia
57	Bangalore	Asia
58	Amman	Asia
59	Kolkata	Asia
60	Karachi	Asia
1	**Curitiba**	North & South America
2	Toronto	North & South America
3	Ottowa	North & South America
4	San Diego, Cal.	North & South America
5	Marlborough	North & South America
6	Arlington	North & South America
7	New York	North & South America
8	Boston	North & South America
9	San Francisco	North & South America
10	Washington	North & South America
11	Chicago	North & South America

	Name of the City	Continent
12	Los Angeles	North & South America
13	Baltimore	North & South America
14	Vancouver	North & South America
15	Dallas	North & South America
16	Philadelphia	North & South America
17	Montreal	North & South America
18	Houston	North & South America
19	Phoenix	North & South America
20	Miami	North & South America
21	Buenos Aires	North & South America
22	Santiago	North & South America
23	Mexico City	North & South America
24	Medellín	North & South America
25	Montevideo	North & South America
26	São Paulo	North & South America
27	Córdoba	North & South America
28	Monterrey	North & South America
29	San José	North & South America
30	Bogotá	North & South America
31	Rio de Janeiro	North & South America
32	Lima	North & South America
33	Porto Alegre	North & South America
34	Guadalajara	North & South America
35	Cali	North & South America
36	Quito	North & South America
37	Curitiba	North & South America
38	Salvador	North & South America
39	Fortaleza	North & South America
40	Rosario	North & South America
41	Brasília	North & South America
42	Guatemala City	North & South America
43	Recife	North & South America
44	Belo Horizonte	North & South America
45	Guayaquil	North & South America
46	Santo Domingo	North & South America
47	La Paz	North & South America
48	Santa Cruz	North & South America
49	Caracas	North & South America
1	Cape Town	Africa
2	Nelson Mandela Bay	Africa
3	Tunis	Africa

	Name of the City	Continent
4	Johannesburg	Africa
5	Durban	Africa
6	Cairo	Africa
7	Pretoria	Africa
8	Alexandria	Africa
9	Casablanca	Africa
10	Douala	Africa
11	Nairobi	Africa
12	Lagos	Africa
1	Melbourne	Australia
2	Sydney	Australia
3	Auckland	Australia