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CONCEPT OF SMART CITIES AND ICT PENETRATION IN EUROPE

Bc. SYLVESTER ELORM AWITTY

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Tutor for dissertation: **doc. Ing. Jitka Komárková, Ph.D.**
Institute of System Engineering and Informatics

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L.S.

doc. Ing. Romana Provazníková, Ph.D.
Dean

doc. Ing. Pavel Petr, Ph.D.
Department Manager

In Pardubice, dated: 1 September 2017

DECLARATION

I hereby declare:

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In Pardubice Bsc. Sylvester Elorm Awitty

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Název

Koncept Smart Cities a penetrace informačních a komunikačních technologií v Evropě

Anotace

Očekává se, že v roce 2050 bude 66 % světové populace bydlet ve městech. V souvislosti s tímto nárůstem čelí městské samosprávné orgány výzvám v oblasti sociální, územního plánovací a dalších organizačních problémů. Rostoucí míra urbanizace představuje pro města vážné a naléhavé výzvy při hledání alternativních způsobů a prostředků pro zvládání problémů jako vysoké náklady na ubytování, dopravní zácpy, zvyšující se míra kriminality, znečištění ovzduší, špatné nakládání s odpady atd. Tyto komplikace donutily vlády, urbanisty a další zúčastněné strany přicházet s inovativní politikou a plány na to, aby města byla udržitelnější, chytřejší a bezpečnější. Koncept Smart cities získal popularitu, je uznáván jako vhodný přístup k řešení městských problémů. Inteligentní města se spoléhají na využívání digitálních technologií a jejich schopnost transformovat a řídit správu, mobilitu, ekonomiku a životní prostředí ve prospěch občanů.

Hlavním cílem diplomové práce bylo zkoumání konceptu Smart cities a penetrace informačních a komunikačních technologií do vybraných zemí v Evropě. Vybraná města byla zkoumána s cílem zjistit nejlepší postupy, které jim pomáhají zachovat udržitelnost a ochranu životního prostředí. Tato práce ukázala, že koncept Smart cities je nový v mnoha částech Evropy.

Klíčové slova: *Smart cities, urbanizace, Internet věcí, penetrace informačních a komunikačních technologií, životní prostředí, Evropa, infrastruktura*

TITLE

Concept of Smart Cities and ICT Penetration in Europe

ANNOTATION

In the year 2050 it is expected that about 66 percent of the world's population will live in cities. With these urban population explosion, city authorities are faced with the challenge of managing an exacerbating number of social, planning, and other organizational issues that will arise as a result of the influx of people in spatially. The increasing rate of urbanization poses a serious and imperative challenge for cities to find alternative ways and means to manage the accompanying complication such as high cost of accommodation, traffic congestion, increasing crime rate, air pollution, bad waste management etc. This has compelled governments, urban planners and other stakeholders to come up with innovative policies and plans to make cities more sustainable, smarter, and safer. This is the reason why smart cities have gained popularity because it is hailed as the solution to urban problems. Smart cities heavily rely on the use digital technologies to transform and control the governance, mobility, economy, and the environment for the benefit of citizens.

The main objective of this dissertation therefore was to examine the concept of smart cities and ICT penetration in some selected countries across Europe. These cities were examined to find out the best practices that have made them successful making cities sustainable and environmentally friendly. This thesis has been able to show that the concept of smart city is novel in many parts of Europe.

Key words: *Smart cities, urbanisation, Internet of Things, ICT penetration, environment, Europe, infrastructure*

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List of Abbreviations

CO_2	Carbon Dioxide
DSL	Digital Subscriber Line
EDI	Electronic Data Interchange
EU	European Union
GDP	Gross Domestic Product
GPS	Global Positioning System
GWh	Gigawatt hours
HGC	Human Chorionic Gonadotropin
IBM	International Business Machines
ICF	Intelligent Community Forum
ICT	Information and Communication Technology
IoT	Internet of Things
IT	Information Technology
NICE	Networking Intelligent Cities for Energy Efficienc
POSCO	**Po**hang Iron and **S**teel **Co**mpany
PPP	Public, Private Partnerships
R&D	Research and Development
RFID	Radio Frequency Identification
UN	United Nations
UNESCO	United Nation’s Educational, Scientific and Cultural Organization
UNGA	United Nations General Assembly
WHO	World Health Organization

INTRODUCTION

The rapid rate of urbanization in recent times has led to a lofty demand for resources such as water, energy, and sanitation along with services such as education and health care (Stimmel, 2015). This situation has necessitated the use of resources sustainably and the need to develop cities to meet the needs of urban residents. Cities are searching for new approaches and solutions that will improve urban transportation, water and waste management, energy usage, and a host of other infrastructure issues that underpin the operation of cities and the lifestyle of urban citizens (Stimmel, 2015). Consequently, cities design, planning and operations need to be innovative to address sustainable development needs pertaining to education, political power, commerce, and environment.

With the continuous increase in urban populations, city authorities are obliged to manage an inflationary number of social, technical, physical, and other territorial complications as a result of the complex gathering of people in limited urban areas (Shcherbakova, 2010). Rapid urbanization produce an urgent call for cities to discover smarter ways to cope with the escalating challenges such as wasteful energy, traffic congestion, among others.

The idea of “smart city” is evolving as a revolutionary approach to mitigate and rectify current urban challenges and make urban living and development sustainable. A smart city represents a community of average technology size, interconnected and sustainable, comfortable, attractive and secure (Joss, 2015). The convergence of technology and infrastructure provides a workable construct for smart cities that forms the basis of this discussion. Their potential to solve challenges relating to the growth of urbanization, participatory governance, environmental issues and worldwide trend of ageing population are some of the reasons why the research in this area is needed.

Smart cities have gained international attention in many countries and both national governments; corporate bodies and international organizations are bound to fund and develop respective technologies and products to tackle these emerging urban problems. The European Commission agenda Europe 2020 strategy seeks to promote smart cities development throughout Europe and is investing more in ICT infrastructure simultaneously with human and social capital development (Hollands, 2008).

The main aim of this thesis therefore is to examine the various ways in which Information

Communication Technology (ICT) Penetration influences Smart cities in Europe (Manville et al, 2014). Special consideration will be given to smart cities infrastructure, and some best practices that have been implemented to ensure the success of smart cities in selected European countries.

1 SMART CITIES

1.1 Concept of Smart Cities

This section is devoted to review literature, scholarly articles, and other sources related to smart cities. This literature reviews critical assessments of previous works done in relation to the research topic being studied (Labaree, 2009). The outline of this section is as follows: definitions and conceptualization of smart cities, characteristics of smart cities, components of smart cities, indicators for measuring smart cities, funding sources of smart cities, factors of smart cities. Motivations for the recent spread of smart cities across developed countries. The concluding section of this chapter focuses on internet penetration and how it influences smart cities.

1.2 Smart Cities Defined

Ever since the term smart city came to be accepted in the scholarly community in 1998 (Anthopoulos, 2015; Anthopoulos et al, 2015) it's definition, meaning and context is still seen as vague and buzzword (Anthopoulos & Fitsilis, 2013; Chourabi et al, 2012; O'grady & O'hare, 2012; Walravens & Ballon, 2013). There exists no acknowledged definition of smart city (Dameri & Rosenthal-Sabroux, 2014). Smart cities are used in many fields of studies ranging from Information and Communication Technology (ICT) (Anthopoulos, 2015); to various ICT characteristics in a city (Allwinkle & Cruickshank, 2011; Chourabi et al, 2012) urban living labs (Komninos, 2002).

Smart cities mainly focuses on the role of ICT infrastructure, although it’s not exclusively limited to ICT infrastructure, it extends to other domains like education (human capital), social capital and environmental interest are recently seen as important drivers of urban growth. Internet technologies have become progressively important for urban development and are increasingly acting as drivers of innovation in areas such as environment, health and business (Hernández-Muñoz et al, 2011). The pillars of smart Cities are deep rooted in the efficient utilization of social capital, human capital and information and Communication technology (ICT) infrastructure to precipitate appreciable and better sustainable economic development as well as improved quality of life (Walravens & Ballon, 2013).

The ‘smart city’ concept has been defined numerously within the literature (Kitchin, 2014).

A city can be labelled “smart” when “investments in human and social capital and traditional (transportation) and modern (ICT-based) infrastructure, fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory government” (Caragliu et al, 2009).

Similarly in the view of (Harrison et al, 2010) “smart city” denotes an “instrumented, interconnected and intelligent city.” They used the word “Instrumented” to denote the ability of acquiring and integrating live real world data by the use of appliances such as sensors, meters etc. “Interconnected” also refers to how these data can be integrated into a computing program that will allow the communication of this information within the various city services. “Intelligent” as in their definition denotes the inclusion of complicated modelling, analytics, optimization, and visual image services to make operational decisions (Harrison et al, 2010).

Smart city refers to the increasing degree to which urban cities are composed of ‘everyware’ (Kitchin, 2014; Maccani et al, 2014). This definition comprises of the visibility of ICT devices built into every aspect of the urban environments (broadband and wireless telecommunication networks, digitally controlled transport infrastructure, camera and sensor networks, and smart building systems). This ICT infrastructure allows people to link up. Cohesive and smart understanding of the smart cities enhances sustainability and efficiency (Gungor et al, 2013; Townsend, 2013). Cities termed smart allows the “intelligent exchanges of information that flow between its many different subsystems. This flow of information is analysed and translated into citizen and commercial services. The city will act on this information flow to make its wider ecosystem more resource efficient and sustainable. The information exchange is based on a smart governance operating framework designed to make cities sustainable” (Komninos et al, 2011).

Similarly defined as smart city as ‘a city may be called ‘Smart’ ‘when investments in human and social capital and traditional and modern communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance’. This definitions of a smart city stresses on the important role played by ICT in linking city-wide services. This definition does not see smart cities as cosmopolitan cities, but it embraces less developed cities (Schaffers et al, 2011).

1.3 Globalization and Smart Cities

Developments in the 21st century has widened and flattened national boundaries and places greater emphasis on a border less world. Globally there seems to be ever increasing concentration of the populations in comparatively few larger cities (Harrison & Donnelly, 2011). Large cities are mostly seen as highly innovative, productive and mostly equipped with social amenities that seem to make life easier for urban inhabitants. These factors collectively act as pull factors that attract numerous people. The rapid influx of new citizens presents overwhelming challenges to their governments.

Globalization is promoted by policies that opens domestic economies and orient them internationally. Years preceding the Second World War, many countries adopted the free-market economic systems that led to increased production potential and creating new possibilities for international investment and trade. Technology has been the principal driver of globalization. Progression in information technology has dramatically altered global economic life. An information technology has equipped individual economic entities such as businesses, governments, consumers and investors with valuable tools for pursuing economic opportunities around the world. Globalization has connected cities worldwide and increased competition for resources, capital and skilled labour. This has led to experimenting new methods of planning, governance, design, finance, construction, urban infrastructure operation and services that are generally called Smart Cities (Sengenberger & Wilkinson, 1995).

Smart cities dependence on ICT has been the innovation and economic hubs that have the capability to attract the Creative Class (Florida, 2003). Smart cities are more flexible to adopting new technologies. Tangible smart cites facilities such as wireless networks, electric buses, metros and trams have increasingly become fashionable in new developments worldwide because all aspiring smart cities need to have these facilities (Lazaroiu & Roscia, 2012; Schaffers et al, 2011). Globalization has created a ‘flat’ world (Friedman, 2000), relating to commodity industries. Smart cities are concentrated in a relatively small number of cities and regions and are attractive (Florida et al, 2008). Smart cities facilitates interaction with its citizen through instant digital connection and support for sustainability through the efficient uses of resources to ensure efficient smart solutions (Bătăgan, 2011).

1.4 Motivation for Smart City Development

The United Nations Population Fund has estimated that between 2008 and 2009, the number of world's population living in cities became proportional to the number of population residing in the rural areas (Nam & Pardo, 2011; Washburn et al, 2009). Figure 1 below elaborates on the rapid rate of global urbanization. It is expected that by 2019 more than 50 % of world's population will live in urban area. Again, figure 2 below also confirms the rapid urbanization in the world. By the year 2050, it is expected that urban population will increase by 3.1 billion meaning that about 64 % of the population in developing countries and 86 % of the western world will be urbanized (Washburn et al, 2009).

Urbanization simply refers to the natural drift of the population from rural areas to urban areas, usually in search for greener pastures such as jobs and better quality of life. Such rapid grow of population is more predominant in developing regions of Latin America, Asia and Africa (Montgomery, 2008). This rising urban population trends poses numerous challenges and risks for cities. The towering rate of urbanization becomes an issue of concern because it puts enormous and rapid strain on public services and resources.

Cities have the edgy task of ensuring that urbanization becomes a blessing rather than a curse for all the citizens. It is therefore imperative to identify strategic plans and actions to make cities smarter, socially friendly, operationally efficient and environmentally sustainable (Carli et al, 2013). This means that cities need to marshal urban infrastructure and services to cater for this unprecedented urban influx to avoid reducing urban living standard.

The possible antidote to the urbanization issues is to transform traditional cities to smart cities (Chourabi et al, 2012). The capability of smart cities to determine citizen' needs and wants in the city, provides the expectation to adjust to these rapid urban change. Some of the possible dimensions and priorities where urban areas can be transformed are public transport system, health care, traffic, efficient energy and resources use. These IoT gadgets can gather and manipulate data from lights, sensors and meters; this can inform decision makers and planners policies aimed at improving services, infrastructure and utilities.

Additionally, smart cities also have the backing of the United Nations (UN) and European Union (EU). The United Nations General Assembly (UNGA) also recently adopted the 2030 Agenda for Sustainable Development. The sustainable development is a plan of action for the

planet, people and prosperity, and it includes 17 Sustainable Development Goals. Both the UN and the EU are of the view that cities ought to play a substantial role in accomplishing the 11th goal i.e. making human settlements and cities more inclusive, safe, resistant, and sustainable. Hence cities will be indispensable for the improvement of social conditions such as poverty reduction, improved education and health as well as improved inclusion (Dempsey et al, 2011; Holden et al, 2017).

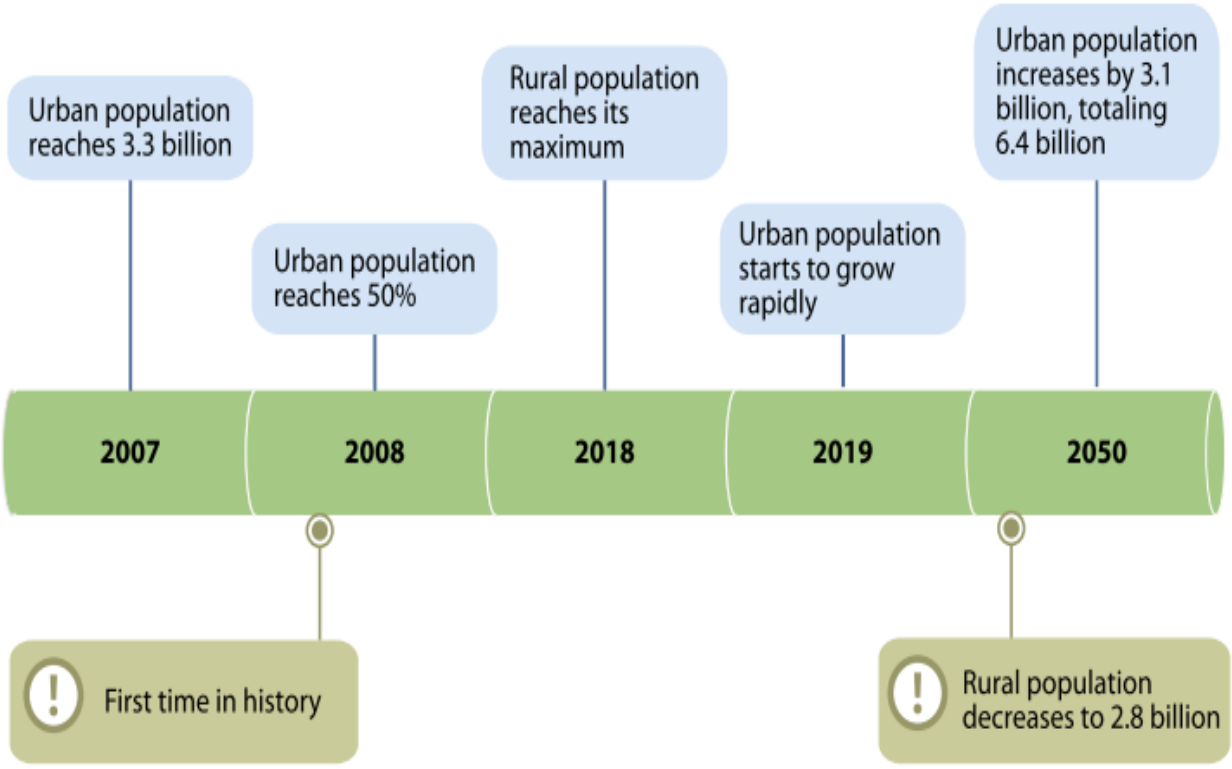

Figure 1: Rapid global urbanization

Source:(Nam & Pardo, 2011).

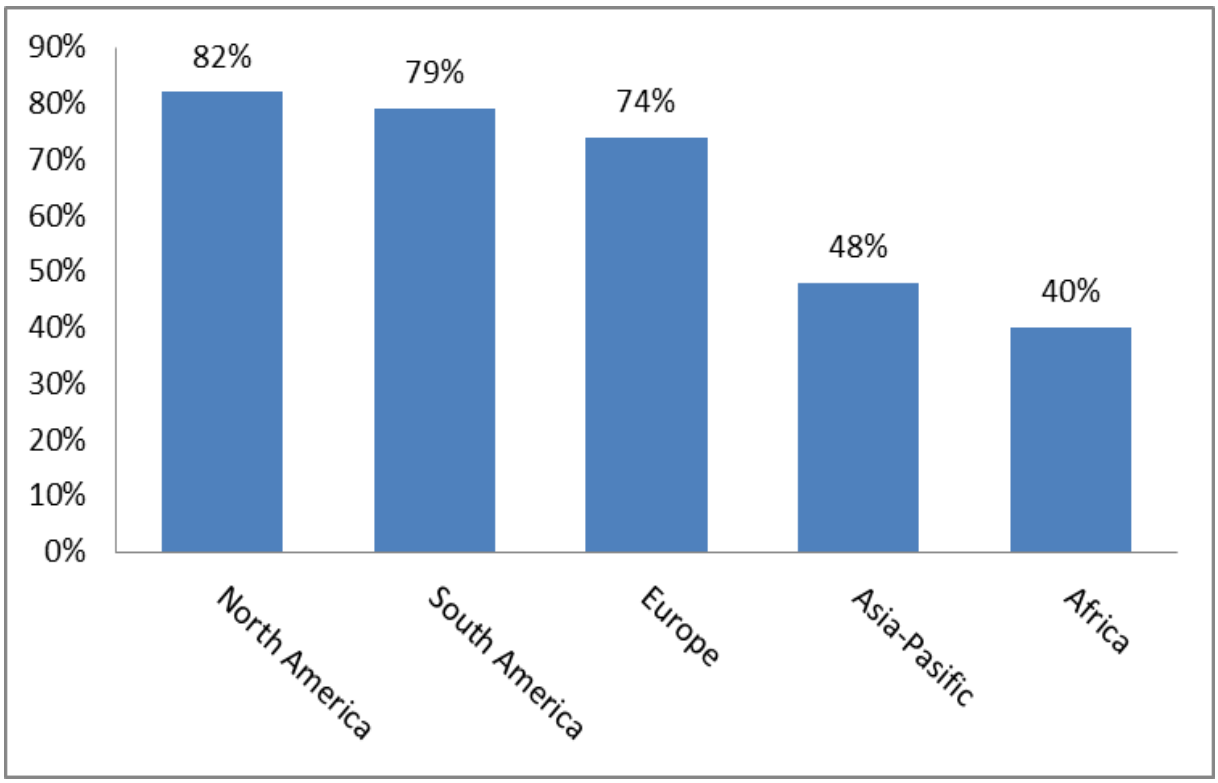

Figure 2: Percentage of population living in cities by region

Source:(Statistics, 2014)

1.5 Characteristics and Components of a Smart City

Smart cities possess certain distinguishing feature that helps identify them. When one wants to define a Smart City these special attributes need to be present. Several authors have come up with six characteristics that must be visible in any Smart City initiative (Batty et al, 2012; Giffinger et al, 2007; Giffinger & Gudrun, 2010; Schuurman et al, 2012).

1.5.1 Smart Economy

Smart Economy simply refers to increased productivity, trade facilitation (e-business and e-commerce), ICT-driven and modern manufacturing and delivery of services, ICT-enabled innovation, as well as introduction of new services, products, and business models (Giffinger et al, 2007). It also includes smart ecosystems and clusters such as digital business and entrepreneurship (Barrionuevo et al, 2012). Smart Economy also comprises local, regional and global inter-connectedness as well as worldwide embeddedness with essential flows of knowledge, goods and services (Barrionuevo et al, 2012).

1.5.2 Smart Environment

The smart environment component entails pollution control and monitoring, green buildings, smart energy (renewable), ICT-driven energy grids, metering, refurbishment of buildings and social amenities, green city planning, resource use efficiency, recycling and re-use and resource (Cohen, 2012). It also includes monitoring and evaluation of urban services such as street lighting, water resource (improved water quality), waste management, pollution control, and drainage systems (Barrionuevo et al, 2012; Batty et al, 2012).

1.5.3 Smart Living

Smart living also focuses on consumption behaviour and ICT-led lifestyles (Thuzar, 2011). Smart living also considers prospect of safe and healthy living in a culturally diverse facilities such as good quality and affordable accommodation (Giffinger & Gudrun, 2010). In addition, smart Living is also connected to lofty levels of social cohesion and capital (Barrionuevo et al, 2012).

1.5.4 Smart Governance

Smart Governance simply means the interactions and the linkages of private, public, civil society to ensure the effective and efficient functioning of the city as one organism (Chourabi et al, 2012). These imply public, private partnerships (PPP) and collaboration among the different social stakeholders simultaneously to meeting the smart objectives of the city. Smart aspirations consider transparency and open data relying on ICT to promote participatory decision-making (Batty et al, 2012).

1.5.5 Smart Mobility

Smart Mobility relates to how ICT can be used to buttress an integrated logistics and transport network (Giffinger et al, 2007; Pichler-Milanović & Lamovšek, 2010). Smart Mobility can encompass cycles, metros, trams, buses, trains, cars, and pedestrian's safety when they use any of these means of transport. Smart mobility entails that general public can have access to relevant information that can help them save time and better commuting efficiency (Cohen, 2012). This also has a global focus, thus the global ecosystems with communal transport and collective alternatives means that people can easily travel around the world easily and at lesser cost.

1.5.6 Smart People

Smart People refer to the efficient and effective manpower base. The manpower need to be highly skilled (e-skills), having access to quality education and training, logistics and human resources capable of improving their creativity and produce innovation (Caragliu et al, 2013; Chourabi et al, 2012). This attribute also allows communities and people to input, manipulate and personalize data to make firm decisions and generate services and products (Giffinger & Gudrun, 2010).

Table 1 below summarises the entire smart city component and their characteristics explained above.

Table 1: Detailed explanation of the characteristics and factors of a smart city

SMART ECONOMY (Competitiveness)	**SMART PEOPLE** (Social and Human Capital)
• Innovative spirit • Entrepreneurship • Economic image & trademarks • Productivity • Flexibility of labour market • International embeddedness	• Level of qualification • Lifelong learning • Ethnic plurality • Open – mindedness
SMART GOVERNANCE (Participation)	**SMART MOBILITY** (Transportation)
• Participation public life • Public and social services • Transparent governance	• Local accessibility • (inter-)national accessibility • Availability of IT –infrastructure • Sustainability of transport system
SMART ENVIRONMENT (Natural Resource)	**SMART LIVING** (Quality Of Life)

• Environmental conditions • Air quality (no pollution) • Ecological awareness • Sustainable resource management	• Cultural facilities • Health conditions • Individual security • Housing quality • Education facilities • Touristic attractiveness • Economic welfare

Source: own compilations based on (Giffinger, 2015)

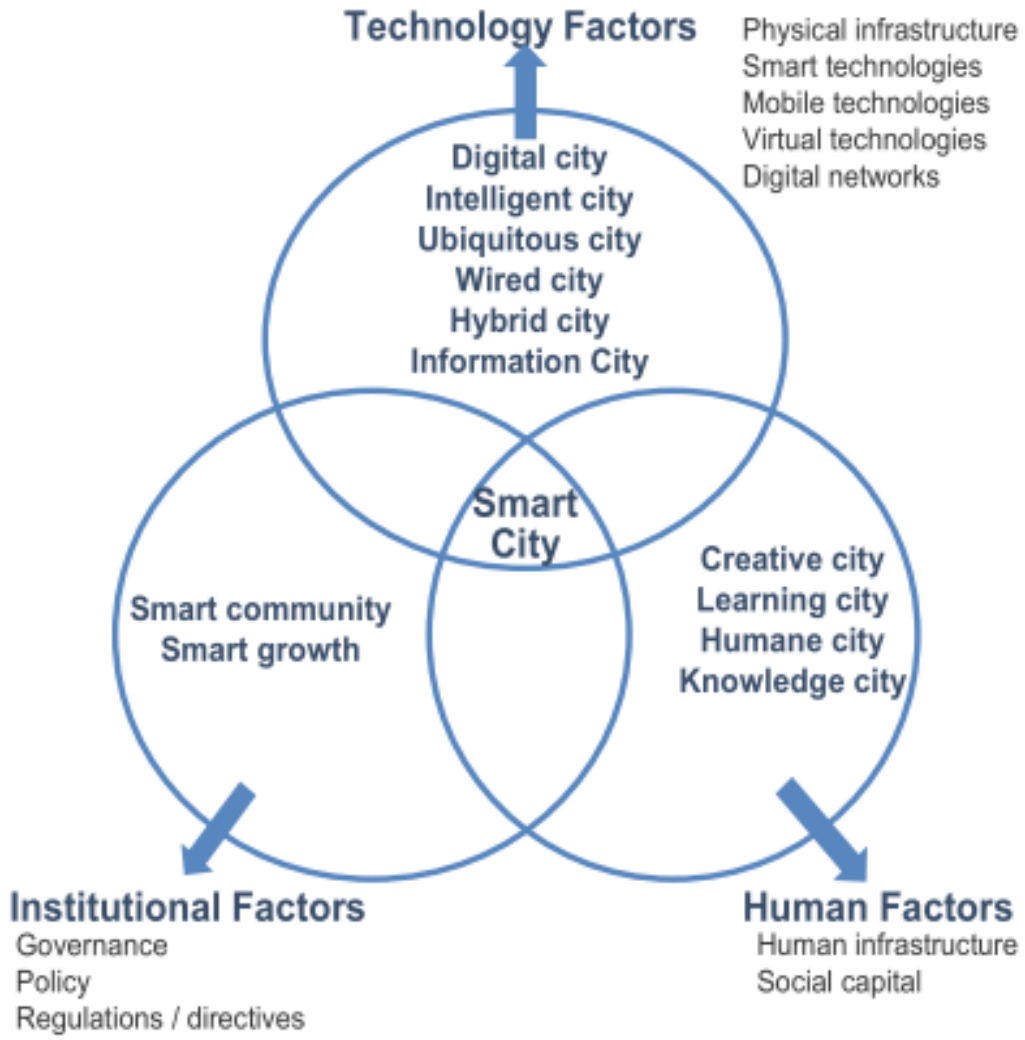

Figure 3: Fundamental components of Smart cities

Source:(Nam & Pardo, 2011)

Table 2: Smart City key dimensions

Key dimensions of a smart city	Source
IT education IT infrastructure IT economy quality of life	(Mahizhnan, 1999)
economy mobility environment people governance	(Giffinger et al, 2007)
technology economic development job growth increased quality of life	(Eger, 2009)
quality of life sustainable economic development management of natural resources through participatory policies convergence of economic, social, and environmental goals	(Thuzar, 2011)
economic socio-political issues of the city economic-technical-social issues of the environment interconnection instrumentation integration applications innovations	(Nam & Pardo, 2011)
economic (GDP, sector strength, international transactions, foreign investment) human (talent, innovation, creativity, education) social (traditions, habits, religions, families) environmental (energy policies, waste and water management, landscape) institutional (civic engagement, administrative authority, elections)	(Barrionuevo et al, 2012)
human capital (e.g. skilled labour force)	(Kourtit et al, 2012)

infrastructural capital (e.g. high-tech communication facilities) social capital (e.g. intense and open network linkages) entrepreneurial capital (e.g. creative and risk-taking business activities)	
management and organizations technology governance policy context people and communities economy built infrastructure natural environment	(Chourabi et al, 2012)

Source: (Albino et al, 2015)

1.6 Smart Cities Architecture and Infrastructure

Smart cities infrastructure plays a crucial role in the development of smart cities, they facilitates both economic and societal development (Chourabi et al, 2012; Nam & Pardo, 2011). Improved physical infrastructure such as broadband internet allows citizens, governments, and businesses to connect, communicate and work together to transform the city (Su et al, 2011).

Governments (national and regional) take lots of measures to tackle challenges associated with growing urbanization and its related problems such as rising poverty, environmental damage and unemployment. A typical example of such case is the Europe 2020 strategy, this initiative seeks to invest in the necessary ICT infrastructure to take advantage of ICT technology to increase effectiveness, and better the quality of life in the European Union (Kassim et al, 2013). Arguably the paramount implementation of smart city infrastructure and architecture is smart grids, which tremendously support renewable resource conservation (Wolsink, 2012). Physical infrastructure influences many aspects of smart city life. Improved ICT infrastructure enhances the service delivery to stakeholders (communities, citizens, businesses) within the city.

Smart city infrastructure influences the intelligent traffic systems in the city. ICT is used to facilitate commuting and easy movement in the city, this is done through ICT-enabled systems such as GPS or road sensors to detect real-time traffic information and the efficient

control of city traffic in a sustainable way (Lin et al, 2012). The efficient management of traffic and parking systems can save time for citizens and reduce cost of commuting. Examples of such infrastructure are smart cycling and shared bikes and intelligent traffic system. They help to reduce CO_2 emission through limited vehicular movements. Key technologies used are data-mining, geo-sensors, smart cards, Radio Frequency Identification (RFID), and tracking.

When it comes to resource management systems, ICT infrastructure can be utilized to improve the efficiency of management city utilities such as electricity (heat storage, smart power systems, smart grids, smart metering, and solar energy management systems). At the same time they can be employed in surveillance management systems for resources like potable water, wastewater and heating efficiency systems (Kellert et al, 2000).

Smart city infrastructure also influences building technology solutions (Morvaj et al, 2011). ICT allows smart buildings to communicate with inside devices and appliances that are aimed at achieving security and energy efficiency. They relate particular lighting and power management of new and existing buildings including outdoor lighting systems. Key technologies include Short-term electricity savings techniques such as light sensors, smart plugs and power management automation software.

ICT infrastructure can be used to make cities citizens Smart. Smart people rely on the ICT to build their skills (e-skills). They can achieve this need through human capital development meaning having access to training and education, capacity management, and human resources. The availability of the aforementioned infrastructure in the city improves citizen's creativity and innovation in general. These infrastructures can also equip people and communities to manipulate and personalize data through befitting data analytic tools and dashboards, enhancing decision.

1.7 Methodologies and Indices for Smart City Performance Measurement

Different assessment and benchmarking indices (methods) have been developed recently to evaluate the impact of smart cities (Albino et al, 2015; Anthopoulos et al, 2015). The smart city initiative involves numerous commitments from governments and other stakeholders, so they need to be evaluated to ascertain if they are yielding their intended results. Policy makers need to have feedback on this expensive project so as not to spend unnecessarily

(Lombardi et al, 2012). Recent smart city performance uses quantitative indicators such as the rating systems to evaluate city performance (Berardi, 2013). This benchmarking strategy provides a metric that enables a possible comparison of different smart cities.

The first measurement indices I will consider are the ones developed by the University of Vienna. They developed an assessment indices that ranked 70 medium-sized European cities (Giffinger et al, 2007). This smart city rankings offers some criteria and then assigns a given score such that cities that meet this criteria are given the highest score and vice versa (Giffinger & Gudrun, 2010). This benchmarking criteria measure cities performance with the various components of smart cities such as mobility, economy, governance, people, environment and smart living. Performance here is measured with soft and hard dimensions such as entrepreneurialism, economic image, innovative spirit, cosmopolitanism, trademarks, creativity, and open-mindedness.

For measurement purposes, smart mobility is lumped into international accessibility and domestic accessibility, accessibility of ICT-infrastructure, sustainable and secure transport systems. According to (Giffinger & Gudrun, 2010) assigning soft and hard attributes provides a true reflection of 'smartness' because of the explicit and implicit intentions involved.

Another measuring index I will consider next is the one developed recently (Zygiaris, 2013). This indicator uses six set of measurement criteria to measure how smart cities are faring. Environmental sustainability is measured in terms of how green the city is. It also measures how innovative the city is, this criteria focuses on the availability of fruitful innovation ecosystem for new business. At the same time city layer smart city must be grounded into possessing an ideal city plan. The interconnection layer component of this index corresponds to the diffusion of green economies city wide. The open integration layer aspect of this index highlights how smart cities are able to communicate and share information. Additionally smart cities need to have the required real-time response system such as monitoring and rapid response to emergencies (the instrumentation layer).

The Intelligent Community Forum (ICF) has developed smart city assessment performance indicators which they use to evaluate smart cities. The Smart 21 Communities metric measures smartness based on five dimensions and they are: a knowledgeable workforce, availability of Wi-Fi and broadband connectivity, innovation, digital inclusion as well as marketing and advocacy. When a city is characterized and possess all these, then it can be labelled a smart city.

To add to the aforementioned (Lazaroiu & Roscia, 2012) have also proposed an assessment a methodology called "the smart city index". The index mostly used by the European Union in the distribution of funds for the 2020 strategic plan. But this metric is not without problems it requires huge amount of information. The approach uses a fuzzy method that allows assigning a set of weights that combines different indicators according to their order of relative importance.

Furthermore (Lombardi et al, 2012) have also come up with a more refined performance measuring system to evaluate smartness of a city. They built this indicator based on revised version of the triple helix model (Etzkowitz & Leydesdorff, 2000). The triple helix model is a framework for analysing the numerous interactions of universities-industries and governments in the knowledge-based. The interactions among these social entities results in the creation, diffusion and assimilation of knowledge and its spillover effects (Leydesdorff & Deakin, 2011; Ranga & Etzkowitz, 2013).

There have been a modification to the triple helix, a new entity has been included in the knowledge creation process that is civil society making it a quadruple helix (Carayannis & Campbell, 2009; Leydesdorff, 2012) this metric measures smartness of each of the four innovative drivers with five clusters (Lombardi et al, 2012). Overall this model is composed of 60 indicators. The table 3 below summarizes all these indicators.

Table 3: List of indicators for smart cities assessment in some rating systems

Source	No. indicators	Indicators of a smart city
(Lombardi et al, 2012)	60	**smart economy:** Public expenditure on R&D, Public expenditure on education, GDP per head of city population, Unemployment rate, . . . **smart people:** Percentage of population with secondary-level education, Foreign language skills, Participation in life-long learning, Individual level of computer skills, Patent applications per inhabitant, . . . **smart governance:** Number of universities and research centers in the city, e-Government on-line availability, Percentage of households with Internet access at home, e-Government use by individuals, . . . **smart environment:** ambitiousness of CO2 emission reduction strategy, Efficient use of electricity, Efficient use of water, Area in green space, Greenhouse gas emission intensity of energy consumption, Policies to contain urban sprawl, Proportion of recycled waste, . . . **smart living:** Proportion of the area for recreational sports and leisure use, Number of public libraries, Total book loans and other media, Museum visits, Theatre and cinema attendance
(Lazaroiu & Roscia, 2012)	18	Pollution, Innovative spirits, CO2, Transparent governance, Sustainable resource management, Education facilities, Health conditions, Sustainable, innovative and safe public transportation, Pedestrian areas, Cycle lanes, Green areas, Production of solid municipal waste, GWh household, Fuels, Political strategies and perspectives, Availability of ICT infrastructure, Flexibility of labour market

2. PROBLEM STATEMENT

The world's population in recent times is increasing astronomically (Bacci, 2017; Raftery et al, 2014). The world population is expected to increase from 5.8 billion to about 7.9 billion in 2020 and further 10.0 billion in 2050 (Bouwman et al, 2013; Ray et al, 2013). It's also been projected that most of the world's population growth in the coming decades will be concentrated in urban areas. The global urban population is forecasted to double by the year 2050, it's also highly expected that by the year 2030, about six people out of every ten will dwell in a city. These figures are expected to increase to seven out of ten by the year 2050. In actual terms, urban resident's population is increasing by nearly 60 million people every year (Dixon et al, 2007). According to (Yantovski & Gorski, 2010) significant part of these new population growths will happen in smaller cities and towns because they have less resources to react to the magnitude of the change instead of megacities.

Such rapid urban population growth represents many dangers and challenges for cities. Cities have the formidable task of ensuring that the urbanization (Giffinger & Gudrun, 2010). This means that cities must align their infrastructure and services to increase the living standard in urban areas.

Therefore the increasing trend of urbanization calls for innovative and new improved ways to tackle the complexity of urban living. Cities need to find out innovative ways to tackle urban problems such as environmental protection, energy consumption, and overcrowding and resource management. The Smart Cities concept has emerged as an innovative strategy for urban areas to address and solve astronomical unemployment, energy management, poverty and inequality, and environmental problems.

The alternative solution to the growing urbanization problems are to metamorphosis cities to smart cities. Smart city are capable of meeting the challenges and needs of its citizen and offering the possibility to alter such rapid urbanization changes. Smart cities should make their priorities in thematic areas such as public transport system, health care, efficient use of resources, traffic and efficient energy use (Nam & Pardo, 2011). The main ideologies of Smart Cities are pivoted in the creation and linkages of human capital, social capital as well as information and Communication Technology (ICT) infrastructure. It heavily relies on Communication technology (ICT) infrastructure to produce more sustainable economic development and a high quality of life.

2.1 Objectives of the Study

The main objective of this dissertation therefore will be to examine the Concept of Smart Cities and ICT Penetration in Europe

2.2 Specific Objectives

1. How architecture and infrastructure transform smart cities
2. Assess the methodologies and indices for smart cities performance measurement
3. Examine funding sources for smart cities development across Europe
4. Analyse best practices of 7 smart cities in Europe and offer recommendations as to how other cities can emulate them

2.3 Sources of Data

Data for this thesis were carefully sourced by the author since there is no unified database for smart cities; I therefore relied on websites of existing city administrations as well as current Smart City project websites, data from Eurostat, European Parliament (mapping smart cities in EU project) among others

2.4 Organization of Chapters

This thesis will be structured as follows: chapter one consist of the introduction, Chapter two focuses on the literature review where literature related to smart cities will be reviewed. Chapter three of this thesis will concentrate on the methodological aspect of this thesis, analysis and discussion of this thesis will be done in Chapter four. The conclusion chapter will be Chapter five. It will also contain the summary of key findings, conclusions and policy recommendations for governments, stakeholders, as well as citizens in final decision.

2.5 European Smart Cities

European parliament in partnership with the Research and energy committee came up with a report in 2014 about Smart cities in EU and their state. According to the report there are about 468 cities scattered across the EU-28 and they have over 100 000 inhabitants each. Out of 468 cities, 240 cities were regarded as smart based on confirmed Smart City activity. These cities were further analysed and evaluated. The evaluation of these European smart cities was benched marked on 6 characteristics of smart city: Smart environment, Smart mobility, Smart economy, Smart governance, Smart people and Smart living. Figure 4 below provides an overview of smart cities across the EU-28.

It can be evidenced from Figure 4 below that across the EU-28 the chunk of smart cities are located in countries such as Italy, UK, and Spain each of these countries have more than 30 smart cities spread across the countries length and breadth. However, other regional economic superpowers like France and Germany have less smart cities. It can be seen that other smaller countries such as Austria, Poland, Romania, Belgium have about 4-10 smart cities. Countries such as Slovenia, Croatia Latvia etc. have not yet implemented any smart cities yet.

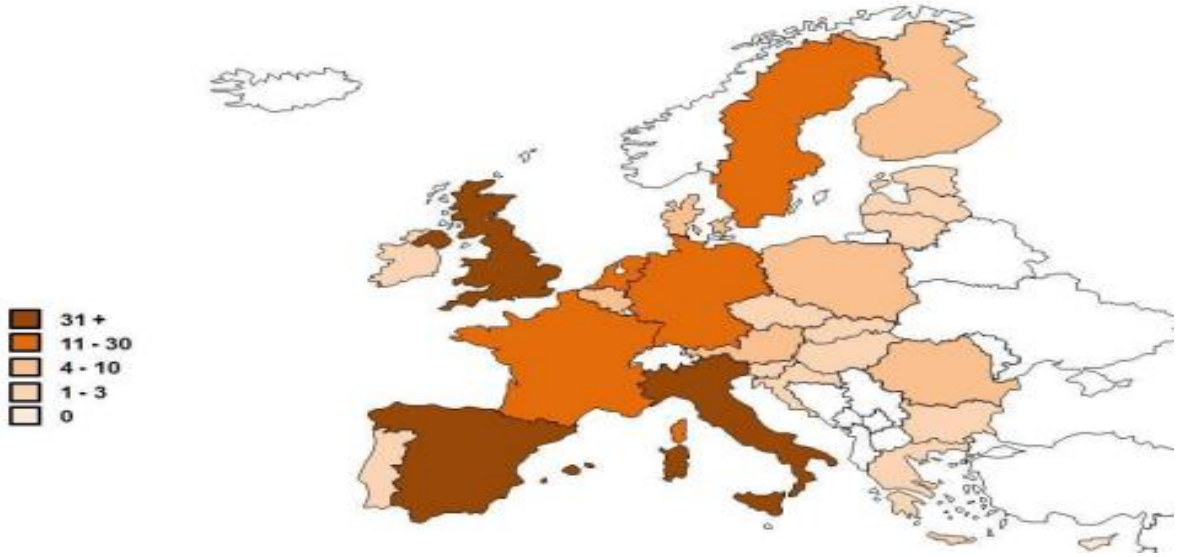

Figure 4: Smart cities across the EU

Source: adapted from (Manville et al, 2014)

2.6 Selected Smart-Cities across Europe

Many countries across Europe have implemented the smart cities project as a means to transform cities development to improve urban life and the environment to make them sustainable.

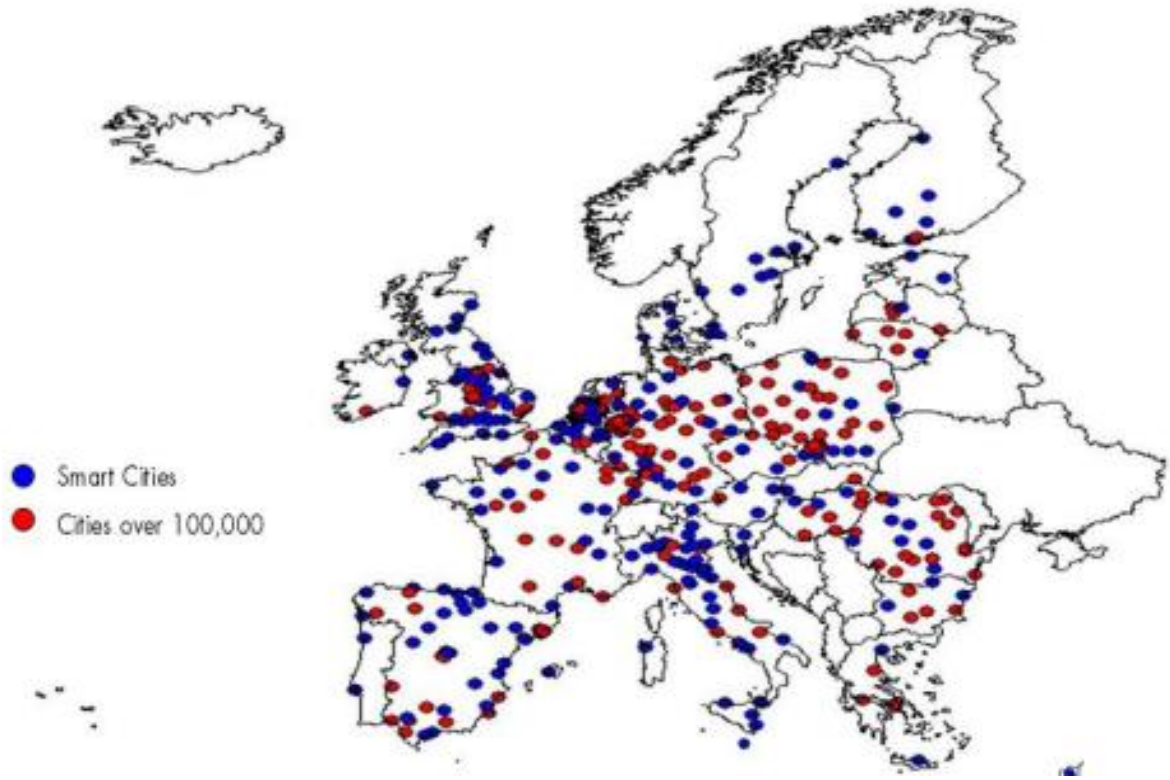

Figure 5: Smart cities distribution across Europe

Source: adapted from *(Manville et al, 2014)*

2.6.1 Manchester as a Smart City

Manchester is an industrial city in the north west of the United Kingdom. It has a population 530,300 as of 2015 (Population and Migration). The city of Manchester has changed radically from been a manufacturing hub to a more service economy. The transition has an urban regeneration and knowledge intensive, creative and innovative economy focus (Carter, 2013). This has made it one of the leading cities for digital developments. All these ambitious programs are enshrined in the Manchester's Digital Strategy drafted in 2008, this paved way for the local digital agenda that initiated the Manchester Smart City project.

One of the principal pillars of the Manchester smart city project is to bring forth innovative and creative digital services and infrastructures through digital innovation. The Digital Strategy was updated in 2012 with a strong focus on making Manchester one of the premier digital cities by the year 2020: This project seeks to enhance and supports towering quality of life for all and sundry. In this regards lots of monies has been pumped into digital infrastructure, providing internet broadband for all.

Best Practices in the Manchester Smart-City

Digital inclusion plays an important role in the cities development and transition (Carter, 2013). This entails broadband internet access and digital education of citizens. The city has relied on ICT to cut down crime, better health and educational attainment and all these have led to improved life in the city. The East serve Living Lab project implemented by the city authority had the aim of increasing digital inclusion in East Manchester. Residential broadband internet penetration increased from 2 % of households in 2001 to 75 % of residents in 2006.

The Manchester smart city Project has the digital inclusion which falls under smart government that ensure people are involved in the decision making process, it also has a strong focus on the energy management (Perboli et al, 2014).

2.6.2 Helsinki as a Smart City

The Helsinki Metropolis is a dynamic world class centre of attraction for business innovation. The city provides lofty quality services, arts and science, creativity and adaptability promote the prosperity of its citizens and bring benefit to all of Finland. The Metropolis is developed as an integrated region close to nature for good living and for business. Helsinki has an urban population of about 1,231,595 (Wikipedia, 2015) hence the most populous municipality in Finland.

The Helsinki smart city is coordinated by, a private non-profit organization called Forum Virium owned by the city of Helsinki. This project has the aim of developing modern urban digital services in partnership with the municipality, private sector, public sector organizations and citizens (Otgaar et al, 2011). The Helsinki smart city primarily focuses on digital services and mobile the development.

Best practices in the Helsinki smart city

In the Helsinki smart city project, there is a smart traffic monitoring that allows the general public to share present traffic information (Volkov et al, 2017). Information such as traffic build up, roadworks and free parking spaces are displayed on public screens and mobile phones. This guides the movement of people, goods and services. The services conveyed traffic information to motorists, public transport passengers, pedestrians and cyclists.

Helsinki smart city has projects concerned with finding novel ways to encourage developers to use open data to produce digital services for citizens. The aim is to ensure transparency in the city decision-making process; this allows city authorities to obtain better feedback from citizens. The Forum Virium Helsinki's Smart City Project involves the development of digital city services intended to make living and travelling in the city easier. Here mobile devices form an integral part in the development of the urban environment (Beatley, 2012). Forum Virium Helsinki Smart City Project embodies the characteristics of smart economy, smart living, and smart mobility.

2.6.3 Barcelona as Smart City

Barcelona is the capital and largest city in Catalonia, and the second most populated municipality in Spain. With a population of 1.6 million within city limits (Nekoukhou & Bidram, 2015). Talks of smart cities cannot be complete without reference to Barcelona which is hailed as a smart trailblazer. When it comes to smart cities analysis several authors rank it between eighth and tenth in the whole world (Caragliu et al, 2013; Cohen, 2012) others even rank it first in the world (Bakıcı et al, 2013).

This ambitious project utilizes knowledge as a propeller for economic growth, the Barcelona smart city initiatives are built around the industrial area 22@Barcelona district (Bakıcı et al, 2013). ICT plays core role in the city's drive of becoming a Smartest City. ICT is utilized to dynamic processes in public business management to make them more effective, transparent, accessible and efficient (Neirotti et al, 2014; Zygiaris, 2013). Barcelona there fulfils
all characteristics inherent in a smart City (Gea et al, 2013).

Best practices in Barcelona smart city

The success story of Barcelona smart city is built around its ability to introduce wireless sensors at parking lots to manage and monitor traffic by showing drivers free parking spaces. Barcelona smart city project also has the initiative on smart mobility such as control of lightening zones, the renowned smart parking that relies on sensors to alert drivers of free spaces at most of its parking lots (Sadowski, 2016).

Barcelona has also introduced numerous e-government services to increase efficiency and transparency of public services through initiatives such as the Open Data BCN initiative that makes public data available to the general public.

The Barcelona smart grids and smart metering are also to ensure sustainable environment, again, the Barcelona solar power hot water law, which makes it binding for city' authority to use solar energy for its heating.

2.6.4 Vienna as a Smart City

Vienna is the biggest and capital city of Austria and it's the primary city with a population of about 1.8 million (Riederer & Buber-Ennser, 2016). In 2011Vienna was ranked as the world's number one Smart City and fourth in the list of European Smart Cities in 2012 (Cohen, 2012). The project is run by the Vienna city administration and it has a strong focus on smart mobility with the objectives of reducing energy use and emissions without compromising the city quality of life (Lombardi et al, 2012). Mobility wise, the city has implemented the eMorail project as a blueprint for cost-efficient, innovative and environmentally friendly mobility answer for commuters. This integrated transport project allows e-car and e-bike sharing service.

Best practices in the Vienna smart city project

Vienna smart city had three of the characteristic present in its smart-city project. These are smart mobility, smart environment and smart living. Some specific initiatives with regards to smart mobility can be seen in the cities mobility solution project dubbed the "eMorail and integrated mobility concept "SMILE". All these focus on easing traffic and free movement of goods and people (Perboli et al, 2014).

With regards to smart environment, the city has also initiated projects such as Vienna Citizens' Solar power plant that taps lots of energy in the summer and store for future use. This reduces the over reliance on crude oil and attain 50 % of their energy from renewable by the year 2030. This project aims to make Vienna energy efficient and welcoming urban development climate by the 2020 (Neirotti et al, 2014). Modern buildings are to be integrated with renewable energy sources such as photovoltaics. It is expected that this will help save about 55-65 % energy. They also have a regulated district heating and cooling plant.

2.6.5 Copenhagen as a Smart City

Copenhagen is the most populous city and capital city of Denmark. The city has a population of 774,312 (as of December 2017), and about 601,448 live in the Municipality of Copenhagen. In (Zipori & Cohen, 2015) meta-analysis of world smart cities, Copenhagen was placed in eighth position and first smartest City in Europe(Cohen, 2012). The Monocle magazine also ranked Copenhagen the third best place in its Quality of Life survey.

The Copenhagen smart city project aims to become the world's premier carbon-neutral capital city by 2025 (Joss, 2015). The city is now implementing a wide range of innovative solutions within the areas of waste management, transport, water, heating and different energy sources to buttress this aim to be energy sustainable. Copenhagen has other objectives to soar the number of people cyclist from 35 % in 2011 to about 50 % by the year 2050 and also to reduce citizen's water consumption from 100 litres per day to about 90 litres per day by the year 2025 (City of Copenhagen, 2012).

Best practices in the Copenhagen smart city

This city has topped the Siemens Green City Index for Europe and also the European Green Capital for the year 2014. The city has taken a stronger initiative to improve commuting across the length and breadth of the city by expanding the network of bicycle lanes. Copenhagen has the ambition to increase the number of cyclist on its streets as a means to reduce Carbon emission (Zipori & Cohen, 2015). The city aspires to be carbon neutral by 2025. In the year 2011, the city had about 35 % of inhabitants commuting to work by bicycle (City of Copenhagen, 2012). City planners took into account cycling infrastructure as crucial parameter to improving the city's traffic flow. Cycle lanes are constructed to reduce commuting time and improve cyclist and pedestrian safety. They have in addition installed traffic lights for bicycles that turn green when cyclists are travelling above recommended speed.

Another distinguishing component of this city project is the Copenhagen Wheel (Li, 2017). This equips bicycles with sensors embedded in their wheels to become Smart. The sensor measure and collects environmental data on congestion, noise pollution, and road conditions. These collected data are constantly sent to city planners to analyse environmental factors and the impact on city infrastructure and traffic flow and at the same time this data is used in the decision-making process when they want to come up with transportation and environmental

issues. Measures have also been taken to ease and enhance switching from bicycles to public transport and bicycles parking spaces. The cycling counters also provide real time information and data that can be used to analyse bicycles traffic flow in the city.

2.6.6 Berlin as a Smart City

Berlin is the largest city and capital of Germany. Berlin is the second most populous city proper in the European Union and the seventh most populous urban area in the European Union (Wessolek et al, 2017). The Berlin Smart City strategy has set itself the following goals

1. reduce use of finite resources to be resource efficient and climate neutral by the year 2050
2. Minimisation the negative side-effects of densely populated urban environment and its negative effects such as stress-related illnesses, environmental pollution and personal safety
3. An increase in prospects for more social participation.

Best practices in the Berlin smart city

The Berlin smart city project has three characteristics present. The city doesn't have any project or initiative that focuses on smart mobility and smart economy. But with the four characteristic they focus on energy self-sufficient that they do through the smart grid system which is a decentralized renewable energy generation scheme (Beatley, 2012). This project is done in partnership with the Siemens Company.

The international showcase for electromobility has about 2,000 electric cars and commercial vehicles, and the city has built about 500 charging points where vehicles can recharge, this is aimed at reducing greenhouse gases while in tandem contributing to improving commuting and energy efficiency and reduced emissions in the city. The city has also taken key initiatives to support the development of electromobiles public transport system i.e. metros, trams, trolleybuses, these are clean city transport and it can help to decrease greenhouse emissions to create synergies to advancing the concept of SMART Grid (Kuschke & Strunz, 2011).

Smart Berlin provides numerous opportunities to foster interaction between universities, research institutions, and companies. Targeted funding policy makes it possible to bring sectors and companies together to create a smart link between these different entities.

2.6.7 Budapest as a Smart City

The Municipality of Budapest is committed to place particular importance on urban features such as green space, social and economic level of air pollution and the accessibility of nature and culture that proves to be a liveable harmonious coexistence place for city dwellers (Csete & Horváth, 2012). The smart Budapest initiative is so far does not have all the characteristic of the six indicators. For now the city strongly focuses on energy efficiency. Budapest is delivering energy efficient in advanced technology with special attention to sustainable environment to determine urban development directions (Auer et al, 2011).

However, this complex approach of smart city does not focus on a single independent area but on the entire city. Smart city is not a goal but a tool for integrated urban development. This serve as a digital computerisation tools for improving the quality of life. Resources exploited in a sensible and knowledgeable manner of technology, could significantly help to improved quality of life in everyday life and making use of modern technology and taking social responsibility to its usage

Best Practices in the Budapest Smart City

The Budapest smart city project also focuses on three characteristic (mobility, people and environment) some initiatives successfully implemented are NICE (Networking Intelligent Cities for Energy Efficiency (González & Rossi, 2012). “The project aims to create a partnership of cities on ICT and energy efficiency”. Although the project is now being piloted, the city has developed various strategies that focus on mobility, people and the environment. The Networking Intelligent Cities for Energy Efficiency (NICE) establishes a strong alliance using ICT to influence energy consumption. This project bears the characteristics of smart environment and smart people. The networking component of NICE also allows learning sessions with expert who shares their views on the smart city concept for the city.

The city also launched an online platform called the *Better Budapest*. This is an eDemocracy Platform that allow citizens to interact and share ideas, knowledge and best practices for popular participation and grassroots actions. This is intended to enable the active participation of citizens in the city developments process.

2.6.8 Prague as Smart City

Prague is unquestionably an important European metropolis (Stachowiak & Stryjakiewicz, 2017). Prague has a population of about 1280508 (Broad et al, 2013). The Smart Prague project started in 2014 and it's expected to run to 2020 (Moravcová, 2017; Sedakovová, 2017).

The Prague SMART City concept, epitomise the following key characteristics as defined by (Jucevičius et al, 2014).

1. Prague is regarded as an advanced and very competitive city in the EU (Metaxas, 2010)
2. Prague is a vital arts and cultural centre inscribed on the UNESCO World Heritage List, this makes it one of the most preferred popular tourist destination in the EU (Hall & Piggin, 2003; Timothy, 2017)
3. Prague has successfully implemented numerous projects that embody all the six dimensions of SMART City (Bătăgan, 2011; Smékalová et al, 2017).

The Prague smart city has been ranked internationally. For instance the Siemens Green Cities Index (2012) ranks Prague 24th green city out of 30 in Europe (Venkatesh, 2014).

Best Practices in the Smart Prague

The SMART Prague 2014 – 2020 initiative is pivoted around three basic axes namely SMART Infrastructure, SMART Creativity and SMART Specialisation.

The smart infrastructure component deals with measure to sustain mobility and also energy savings to achieve energy efficiency. The city has recently been exploring increased use of electric buses and trolleybuses. A fourth metro line is under construction. The main transport provider is the Prague Public Transport Company; a.s. Prague has developed a user-friendly web application (IDOS, DPP) that makes it easy for passengers to arrange their travel plans at the comfort of their homes through the internet. Also the main Prague transport provider DPP has made it easier to transport bicycles metro and trains and the have also provides adequate number of seats handicapped persons and baby carriages.

Prague has a detailed web portal that facilities governance (Hub & Zatloukal, 2009). This website provides a broad range of information on city's activities, such as budget, grants, maps and other city's activities. This allows citizens to utilize e-Government services to engage public administrators.

3 CASE STUDIES APPROACH

The Case study research approach is pertinent when researchers want to explore and understand complex real-life phenomenon. Case studies are mostly employed because they provide robust research method and can be utilized for in-depth investigation. According to (Zainal, 2017) the case study research method "as an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used." There are basically three main categories of case studies- descriptive, exploratory and explanatory case studies (Zainal, 2017).

Other scholars such as (Zakaria, 2017) has distinguished between other categories such as evaluative and interpretive case studies The interpretive case studies type allows the researcher to explain data by through abstract categories based on assumptions. On the other hand evaluative case studies allows researcher to expound a given situation by adding their personal judgement. The choice of the case study approach for this thesis is based on the fact that it provides in-depth qualitative accounts of complexities of real life issues which cannot be done through survey (experimental research).

I used the case study approach to define the specific success of smart cities that have been implemented in many European countries to allow an objective and consistent assessment of the success of Smart City programs and projects (Pucher et al, 2010). Here the focus was on assessing the best practices and the enabling environment that has driven innovative and productive Smart Cities.

3.1 Selected Smart City Comparison

In this part I focus on comparing 8 European smart-cities by considering some initiatives undertaken to improve the quality of life and the environment thereby making the city smart. The case studies were selected based on how successful the city has improved living standards as well as how it contributes to environmental sustainability. This entails a fertile atmosphere guided by a well-defined vision that allows popular participation of important actors and the effective and efficient configuration of its processes (Errichiello & Marasco, 2014).

In order to analyse smart cities in Europe, I used the indicators proposed by the European Parliament mapping Smart Cities in the EU report. This report measured smart cities by the 6 dimensional components. So they assessed how each city termed "smart" was performing with regards to smart mobility, Smart Governance, Smart People, Smart Economy, Smart Living and Smart Environment.

Numerous authors have also used these indicators to measure smart city performance (Giffinger et al, 2007) (Giffinger & Gudrun, 2010; Schuurman et al, 2012) The comparison will be done such that, I will compared 7 selected smart cities against these aforementioned indicators to see the initiatives taken to achieve those components. The 6 indicators are demonstrated in figure 6 below. It is believed that when all these components are working better, then a city can be labelled smart. The selected smart cities selected for this dissertation are Manchester, Barcelona, Vienna, Budapest, Copenhagen, Helsinki, Berlin and Prague. They were randomly selected based on the fact they have successfully implemented the smart cities project and have been seen as success stories that can be emulated in other cities and countries aiming to go smarter.

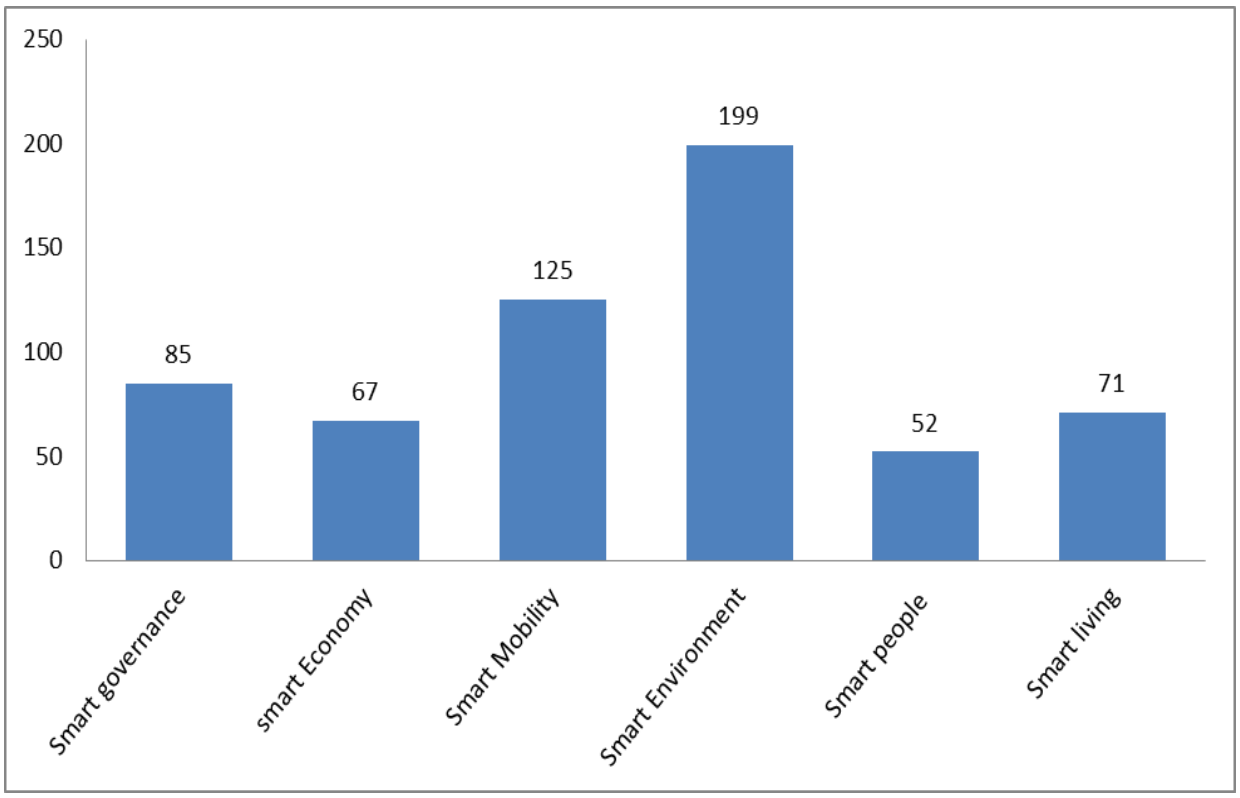

Figure 6: Total number of smart cities with the various indicators

Source: ***(Manville et al, 2014)***

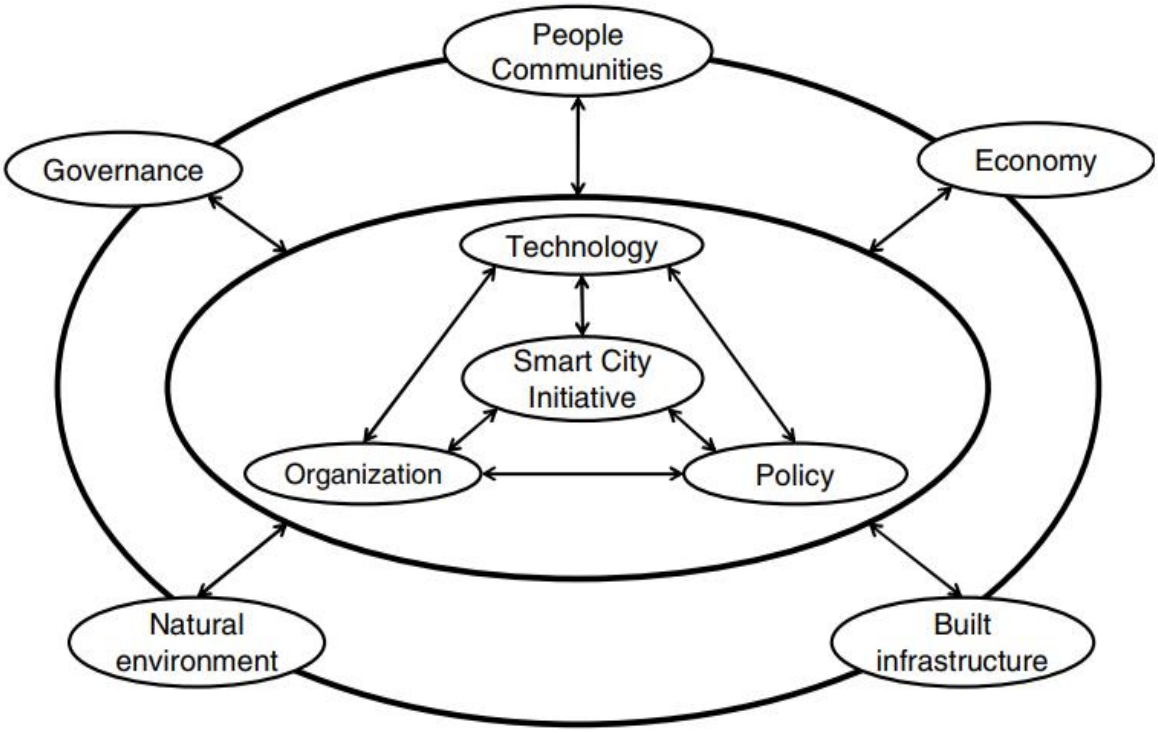

Figure 7: smart-cities characteristics

Source: (Chourabi et al, 2012)

It can be seen that smart-cities across Europe strongly focus on the smart environment and environmental sustainability. A total of 199 cities focused on this component. This was closely followed by smart mobility which pertains to the ease of commuting good and people from one place to the other. 125 countries implemented initiatives in this regard. Smart governance was also the third area where European smart-cities focused on immensely on, 85 cities in different countries implemented projects and activities to increase citizen's participation. Additionally 71 cities also had a strong focus on smart living. 67 cities also focus on smart economy aspect of smart-cities. The least area of smart-cities characteristic that European smart-cities focused on was smart people; only 52 cities implemented this characteristic across cities in the EU.

(Anthopoulos et al, 2015) also proposed to measure and benchmark smart cities with six parameters namely Living Mobility, People, Economy Governance, and Environment. Many proposals for comparison refer to these components. Despite this, it worth mentioning that there exist numerous individual benchmarks and complex indicators for comparing, measuring and benchmarking smart cities.

Table 4: comparing selected smart-cities across Europe

Smart Cities	Countries	Population of a city	Project	Governance	Economy	Mobility	Environment	People	Living
Manchester	UK	503,000	1	X	X	X	X	X	X
Vienna	Austria	1,714,142	2	-	-	X	X	X	X
Barcelona	Spain	1,620,437	22	X	X	X	X	X	X
Helsinki	Finland	588,549	2	X	X	X	X	X	X
Copenhagen	Denmark	541,989	5	X	X	X	X	X	X
Berlin	Germany	1,353,186	1	X	-	-	X	X	-
Budapest	Hungary	1,727,621	1	-	-	X	X	X	-
Prague	Czech Republic	1,335,000	1	-	-	X	X	X	-

Legend: x *characteristic present*, - *characteristic not present*.

Source: ***(Manville et al, 2014)***

From table : 4 above, it can be seen that out of the seven selected countries considered for this work, Manchester, Barcelona, Helsinki, and Copenhagen are the best forming smart-cities because they have strong focus on all the aforementioned characteristic of smart-cities. All the numerous projects carried out by cities administration had each of these components.

Smart Economy

Several indicators such as unemployment, household disposable income, share of the region in GDP, share of unemployed persons etc. are used to measure the economic performance (Tan et al, 2017). I used this indicator, but I couldn't get enough data on all the cities, so the comparison was done just on those with data.

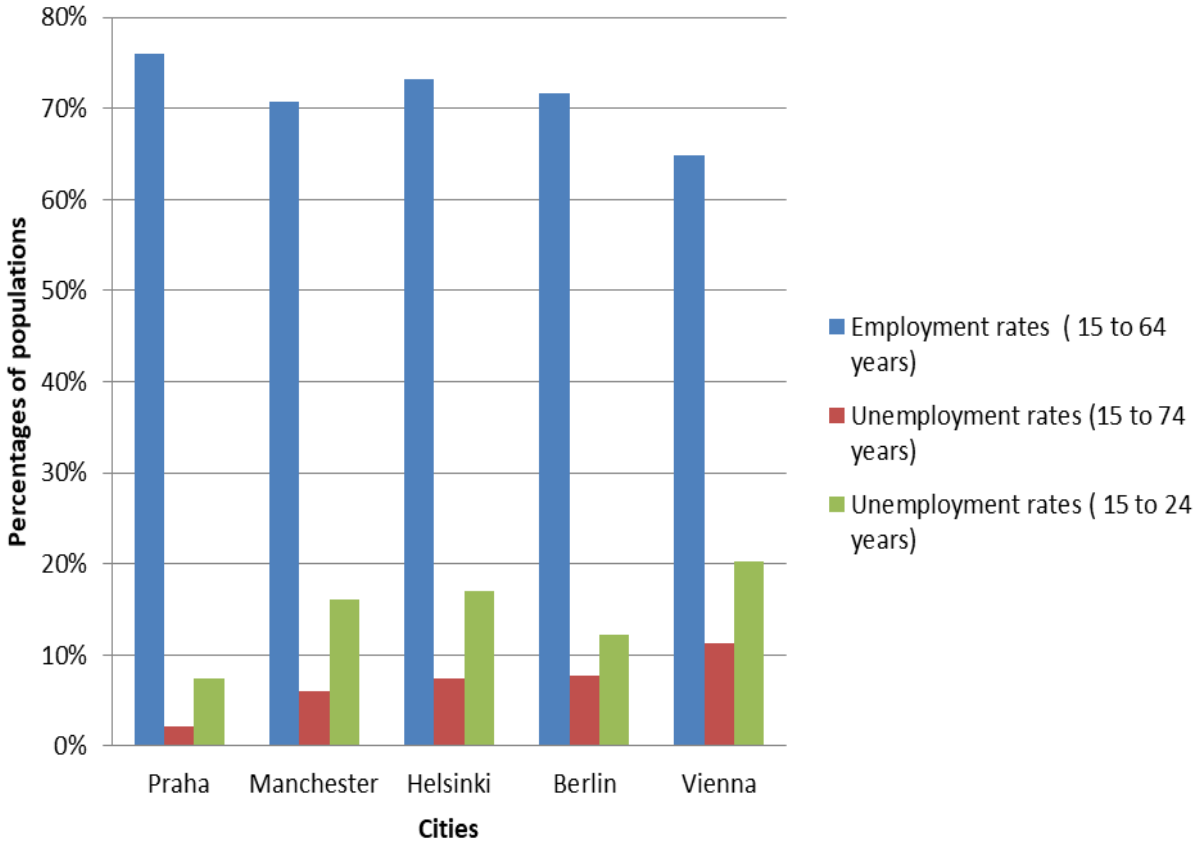

Figure 8: Smart Economy Comparison

Note. 2014 data

Source: own with data from Eurostat

From figure 8 above it can be seen that Prague had the highest share of the population aged 15 to 64 employed among the chosen smart cities. Vienna had the lowest about 65 % of the city's population were employed. When it comes to cities unemployment statistics, Vienna had the highest share of unemployment for the working population age group. Prague had the lowest.

Figure 9: Gross domestic product (GDP) at current market prices

Source: own with data from Eurostat

From figure 9 above, Prague has the highest Gross domestic product (GDP) at current market prices because of the small size of population. Manchester had the lowest because its population is huge.

Smart People

Educational attainment is the most essential indicator used to assess smart people in the society. The smart living component comparison was limited by data constraint. So I compared 2 cities and their educational attainments.

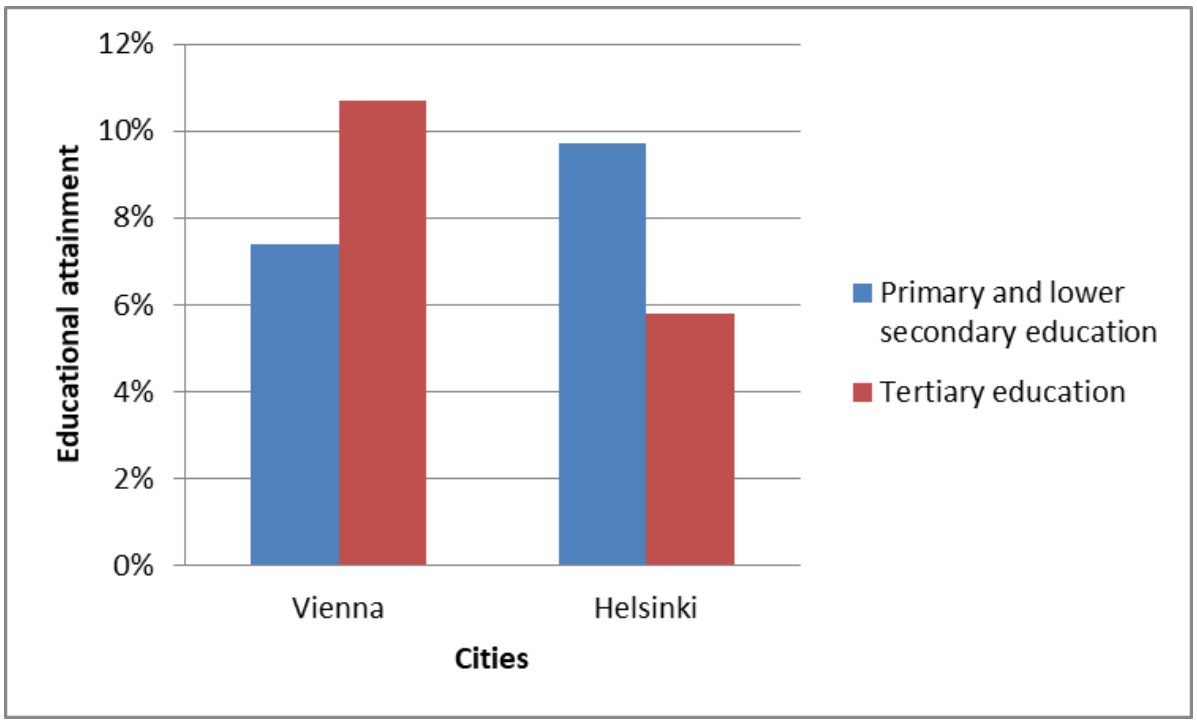

Figure 10: Percentage of population enrolled in primary, secondary and universities (2014)

Source:own with data from Eurostat

From figure 10 above, it can be that the number of people enrolled in peimary and secondary schools represented about less than 10 % in Helsinki and about less than 8 % in Vienna. On the other hand Vienna had more people enrolled in tertiary educational institutions almost about 1 % while less tha 6 % in Helsinki.

Table 5: Prague educational enrolment for the period 01.09.2016 - 30.06.2017

Educational facilities	universities	.
Educational facilities	Higher professional education1	37
Educational facilities	Secondary education1	185
Educational facilities	základní vzdělávání1	269
Educational facilities	Pre-school education1	410
Classes	Secondary education1	2,876
Classes	základní vzdělávání1	4,639
Classes	Pre-school education1	1,801
Children in pre-primary education1		42,711
Pupils	Secondary education1	63,262

Pupils	základní vzdělávání1	98,126
Students	Higher professional education[1]	5,644
University students	total	.
University students	citizenship Czech Republic[2]	38,394

Code: UD-1515707105272

1 Period: 01.09.2016 - 30.06.2017

2 Period: 01.09.2015 - 30.06.2016

Source: Czech Statistical Office (CZSO)

From table 6 above, Prague had about 258354 people enrolled in all the levels of education. This represented about 48 % in basic schools and 31 %secondary schools, 18 % in universities and 3 % were in higher professional educational institutions.

Smart Governance

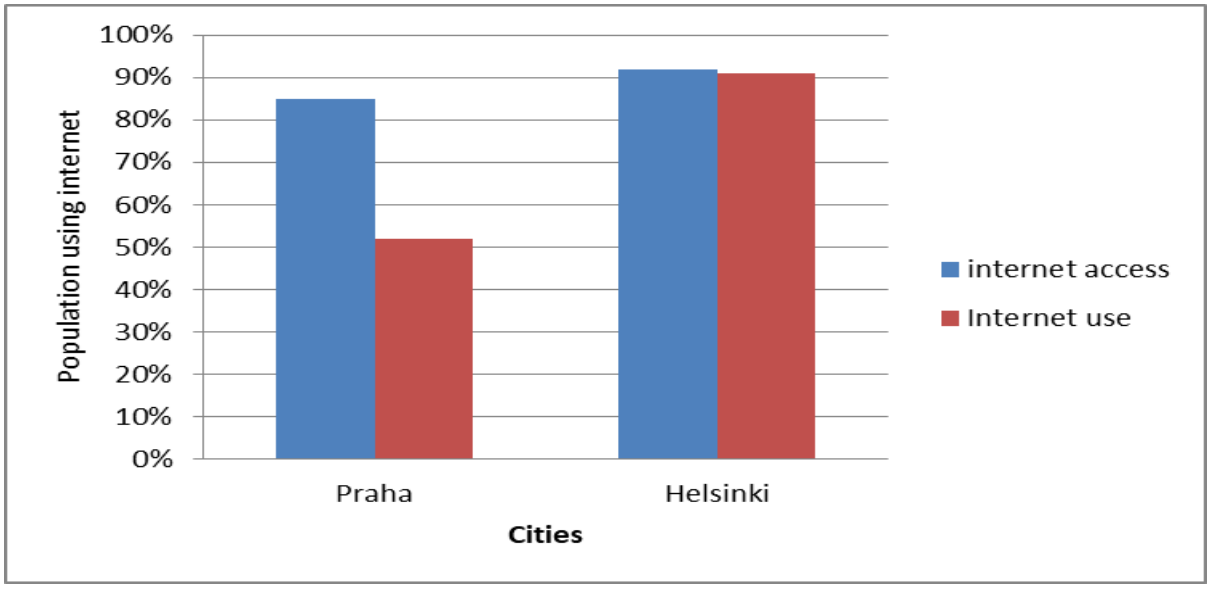

Figure 11: Internet use and access

Source: own based on data from Eurostat

From figure 11 above, it can be seen that Finland has the highest percentage of its population with access to and using the internet (a little over 90 %). Then Praha has about 50 % inhabitants using the internet and over 80 % with internet access.

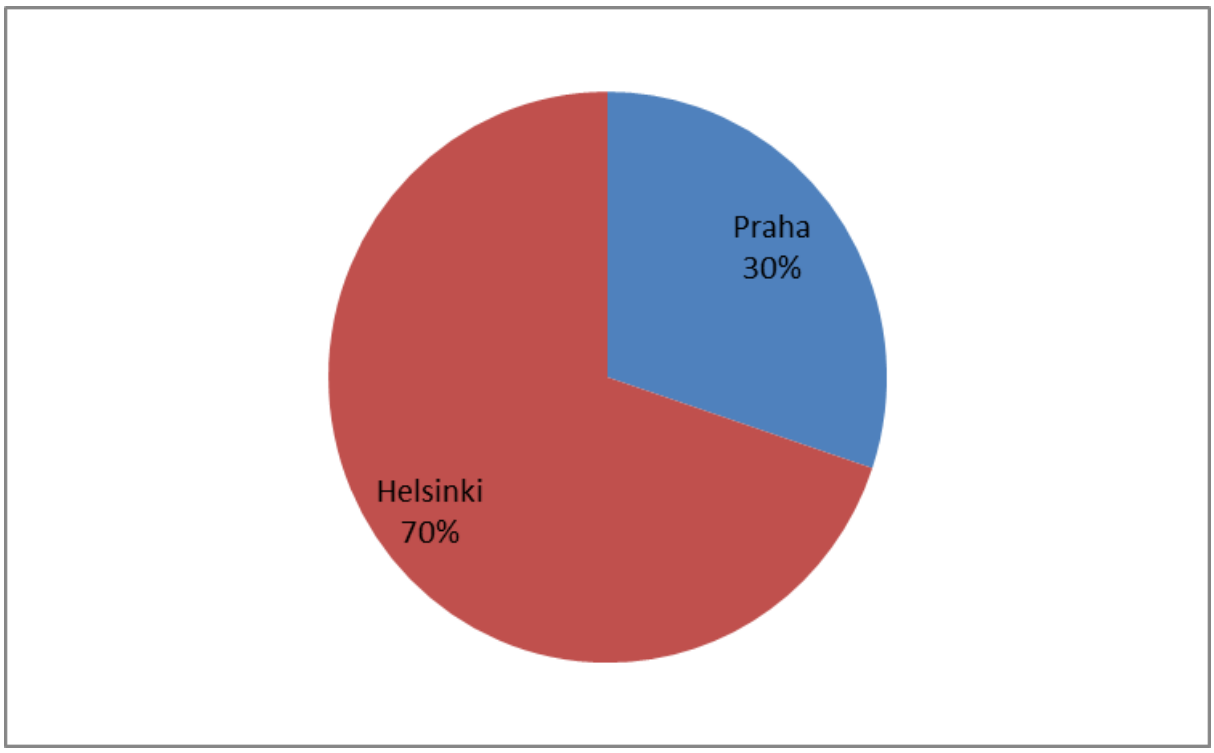

Figure 12: Percentage of people that used the internet to contact a public official

Source: own elaboration with Eurostat data

From figure 12 above, it can be seen that more people resorted to communicate with their public officials using the internet (social media) in Helsinki than in the Prague province.

4. COMPARING ICT AND INTERNET PENETRATION

Internet Penetration simply refers to the total percentage of a country's population that uses the Internet. ICT in particular is a prerequisite and essential to cities initiative and development. Smart cities and its component features such as intelligent transportation, smart grids etc. are all built on ICT. ICT has a great potential to further promote sustainable urban growth (Godschalk, 2004). These technologies can have far-reaching impacts on individuals, communities, businesses, industrial sectors and governments. ICT usage has enabled information proliferates, and knowledge sharing. ICT is an important element in innovations and has sped up and contributed to the rapid rate of globalization we are witnessing. It influences the socio-economic and environmental development of cities and countries as a whole.

ICT development in each country is represented by five national indicators using internet access that is the percentage of households with access to the Internet connection at home, broadband-percentage of households that have broadband connection, e-commerce-percentage of individuals using the internet to purchase goods and services online and finally e-government-percentage of individuals using the internet (online) to interact with public authorities. I used the national level ICT baseline data to capture city's ICT abilities because of data limitations.

From figure 14 below, it can be envisaged that in the year 2009, Denmark had the highest population usage of the internet; this was closely followed by Finland, Germany, and the United Kingdom. The Czech Republic for instance had about 60 % of its inhabitants using the internet for various reasons. The country that had the lowest internet penetration was Spain with a penetration rate of about 59 %. Then in the year 2010, Denmark again had the highest internet penetration (88 %), Finland (86 %), the United Kingdom (83 %), Germany (80 %), Austria (74 %), the Czech Republic (66 %), the least internet users among these selected countries was Spain with a penetration rate of (64 %). I relied on the national data due to the difficulty in obtaining data on these smart cities.

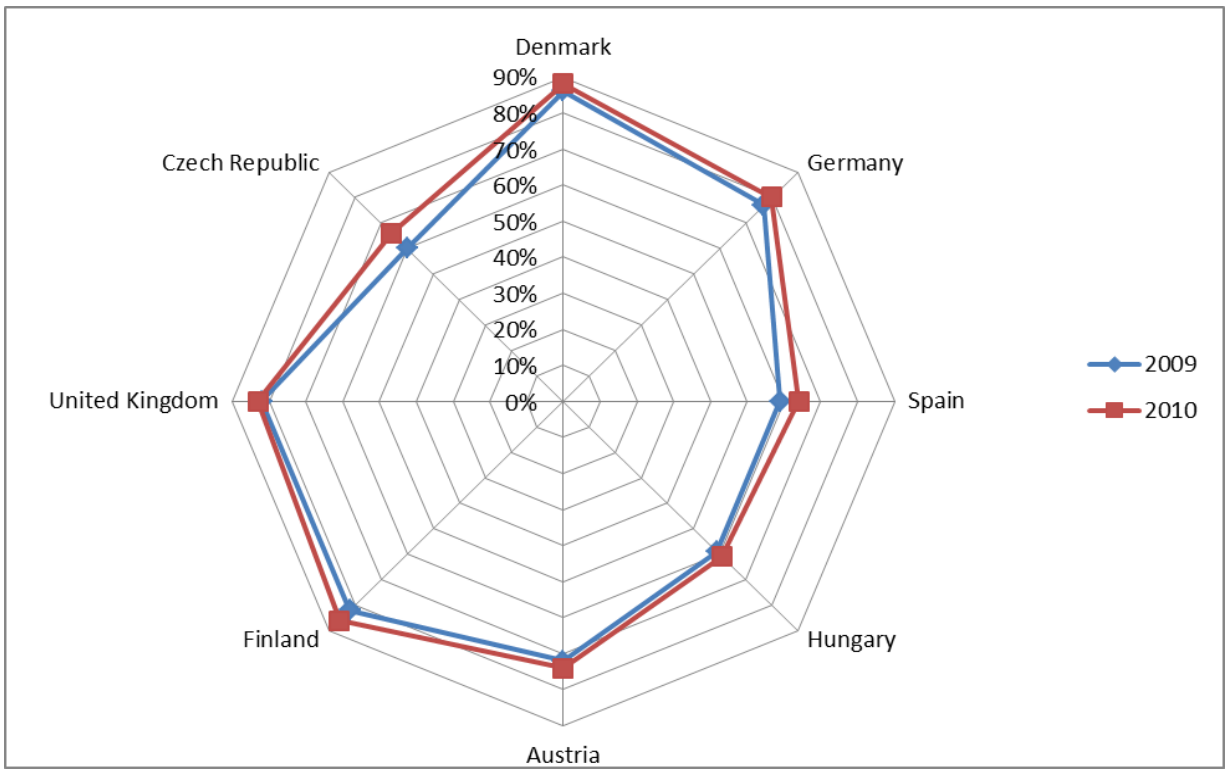

Figure 13: Internet penetration in selected EU countries in 2009 & 2010

Source: Own with data from Eurostat

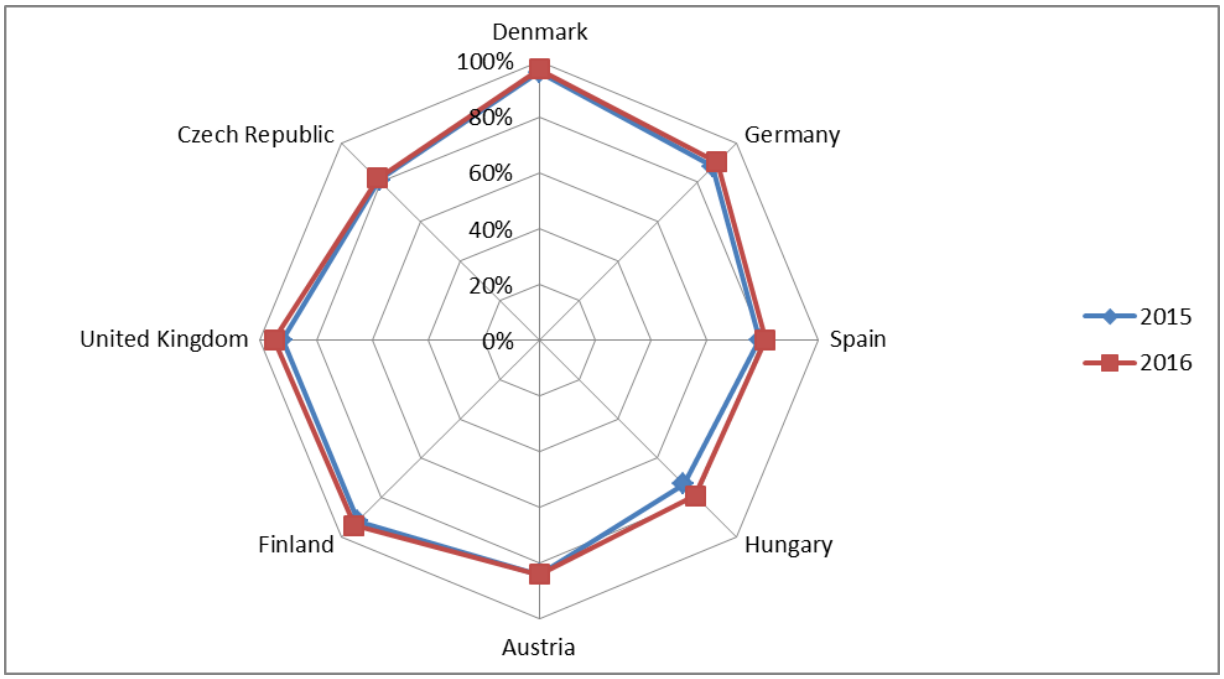

Figure 14: Internet penetration in selected EU countries in 2015 & 2016

Source: own with data from Eurostat

From figure 15 above, Denmark again had the highest rate of internet penetration of 96 %, Finland and the United Kingdom had the rates of 92 %. The Federal Republic of Austria penetration rate was 84 %. The Czech Republic 82 % and Spain had the lowest internet penetration rate among these selected countries (81 %).

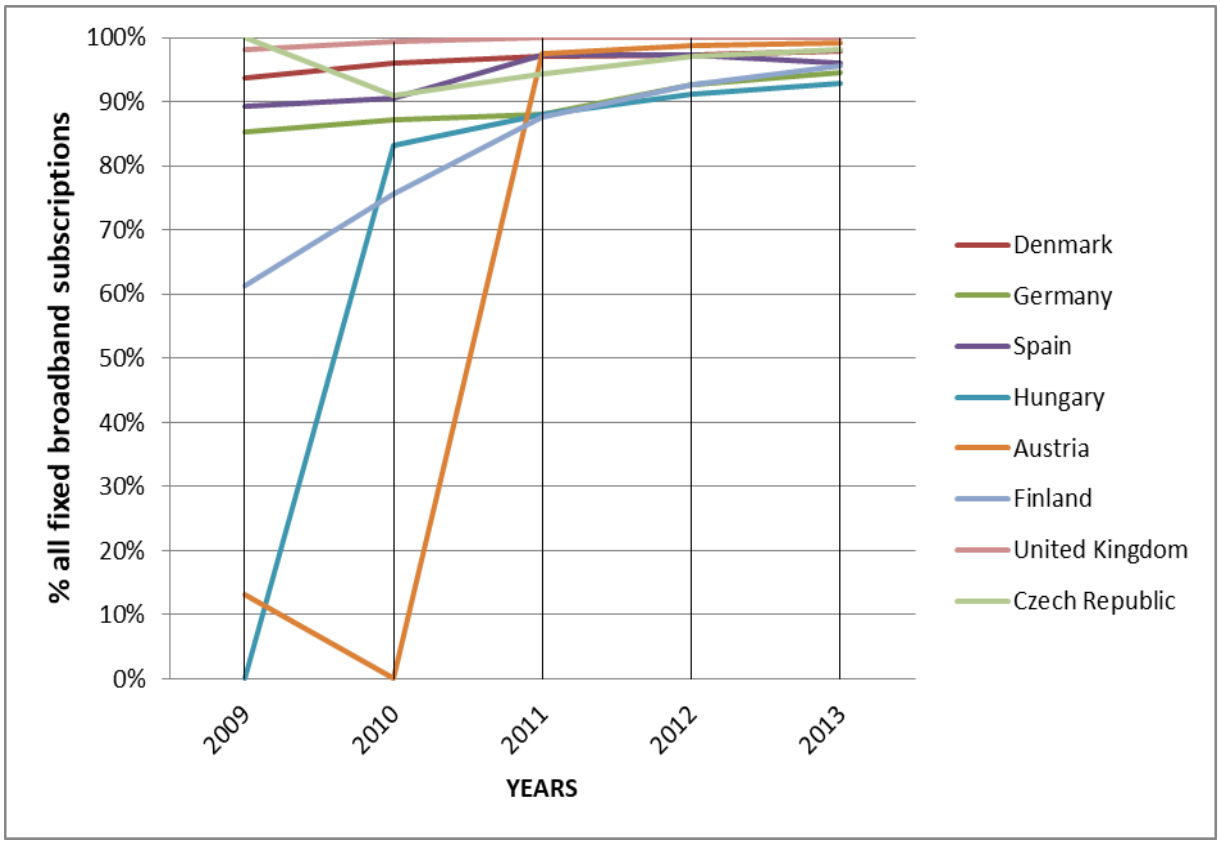

Figure 15: Fixed broadband – subscriptions by speed

Source: own with data from Eurostat

Note: fixed broadband subscriptions which basically talks about the total number of subscriptions to broadband technologies with download speeds of 256 kbit/s or more using mediums such as fibre-to-the-home, DSL, cable modem, and other fixed technologies. This indicator measured the number of subscriptions per 100 people and in the total number of subscriptions. From figure 16 above, Denmark and Germany has the highest number of inhabitants using the broadband with the speed of 2Mbps (93.7 % and 85.4 % respectively). Spain Hungary and the Czech Republic had the lowest share of connection to fixed broadband.

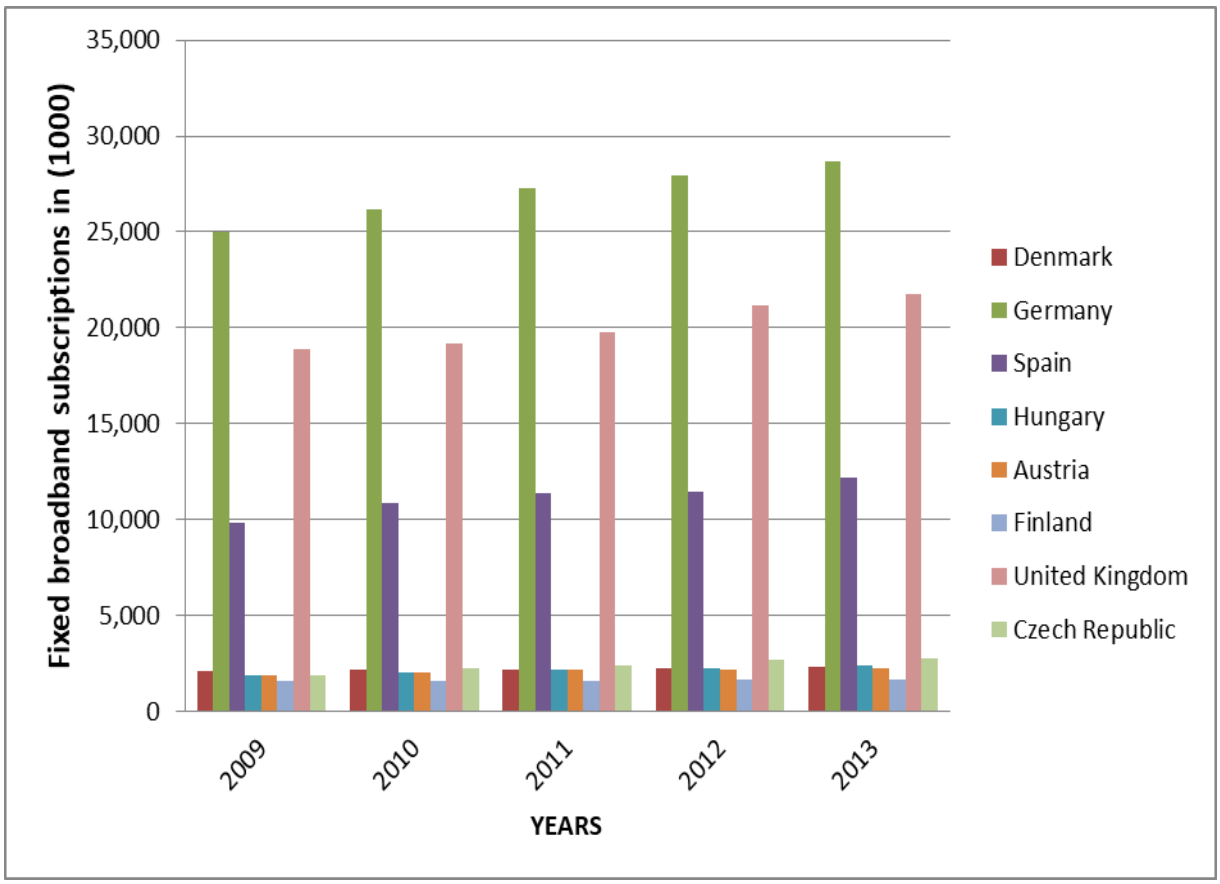

Figure 16 : Fixed broadband – subscriptions and penetration

Source: Own with Eurostat data

Note: The Penetration rate is simply the percentage (%) of a country's population that are subscribers to a fixed broadband.

From figure 17 above, countries such as Germany, Spain and the United Kingdom, and in the other least populated countries such as Austria, Finland, Denmark, Czech Republic etc. there was a significant increase in the number of broadband subscribers.

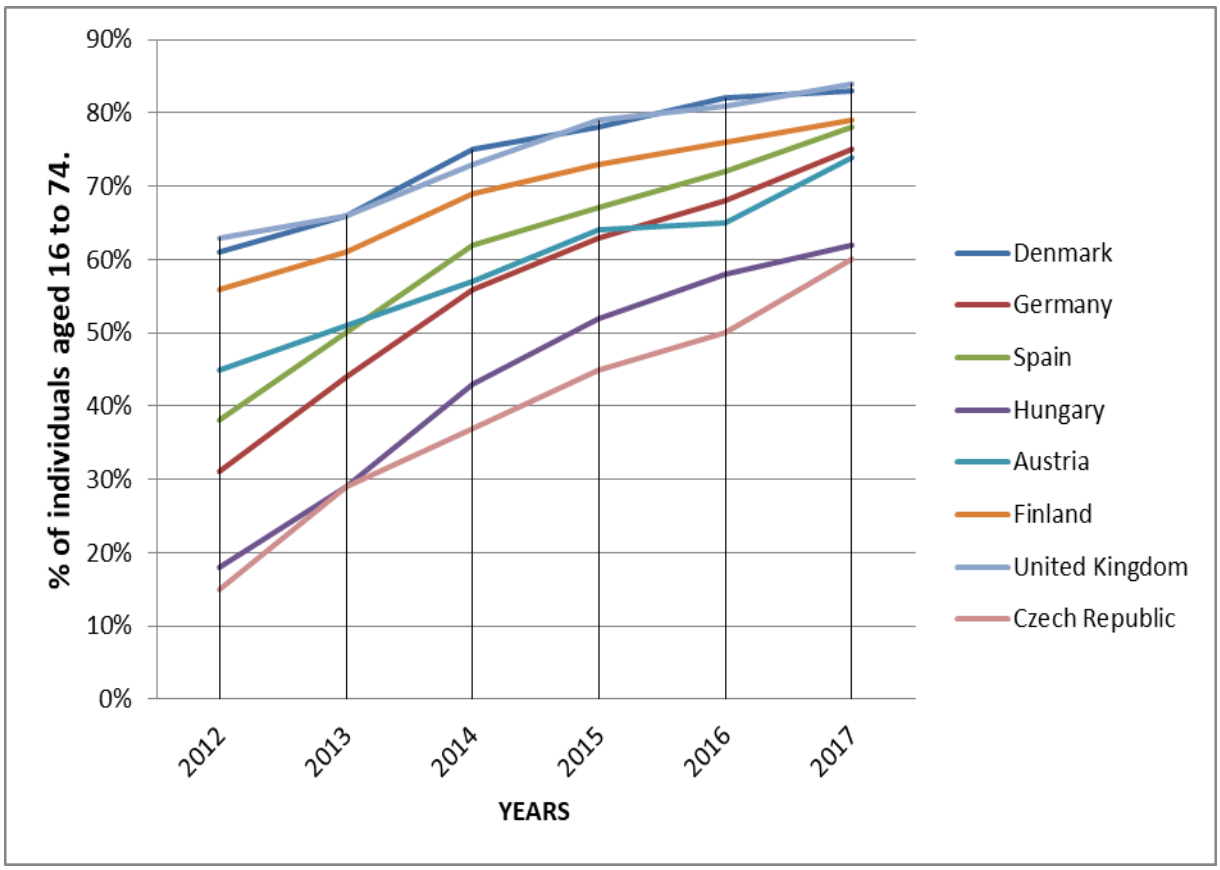

Figure 17: Individuals aged 16-74 using mobile devices to access the internet

Source: own with Eurostat data

From figure 18 above, it can be seen that in the year 2012, Hungary had about 18 % of people aged 16-74 using mobile devices to connect to the internet, whilst in Denmark and the United Kingdom had more that 60 % of this age group connecting the internet using mobile devices. This figures inflated to 62 % for Hungary, Denmark, 83 %, Germany 75 %, Spain 78 %, Austria, 74, Finland 79 % and the United Kingdom 84 %. This demonstrates that people in these countries used the internet for many reasons.

4.1 Electronic E-commerce

E-commerce simply refers to transactions carried out electronically using the Internet. Electronic commerce depends on technologies such as electronic data interchange (EDI), mobile commerce, electronic money transfer, Internet marketing, and online transaction processing. Figure10 below shows that in Denmark, the number of people that undertook transactions electronically increase from the year 2010 (54 %) Danes conducted transactions electronically, this increased to 66 % in 2014. The United Kingdom had the highest share

of citizens conducting their transactions online for the selected countries. About 60 % of Britons purchased a good or service online in 2010, 72 % in 2014 and 78 % in 2017.Hungary, Czech Republic and Spain were the countries with the lowest share of citizens conducting transactions among all the selected countries. In 2010, 17 % of Spaniards conducted a transaction electronically, this rose to 28 % in 2014 and finally in 2017, 40 % bought at least something from online.

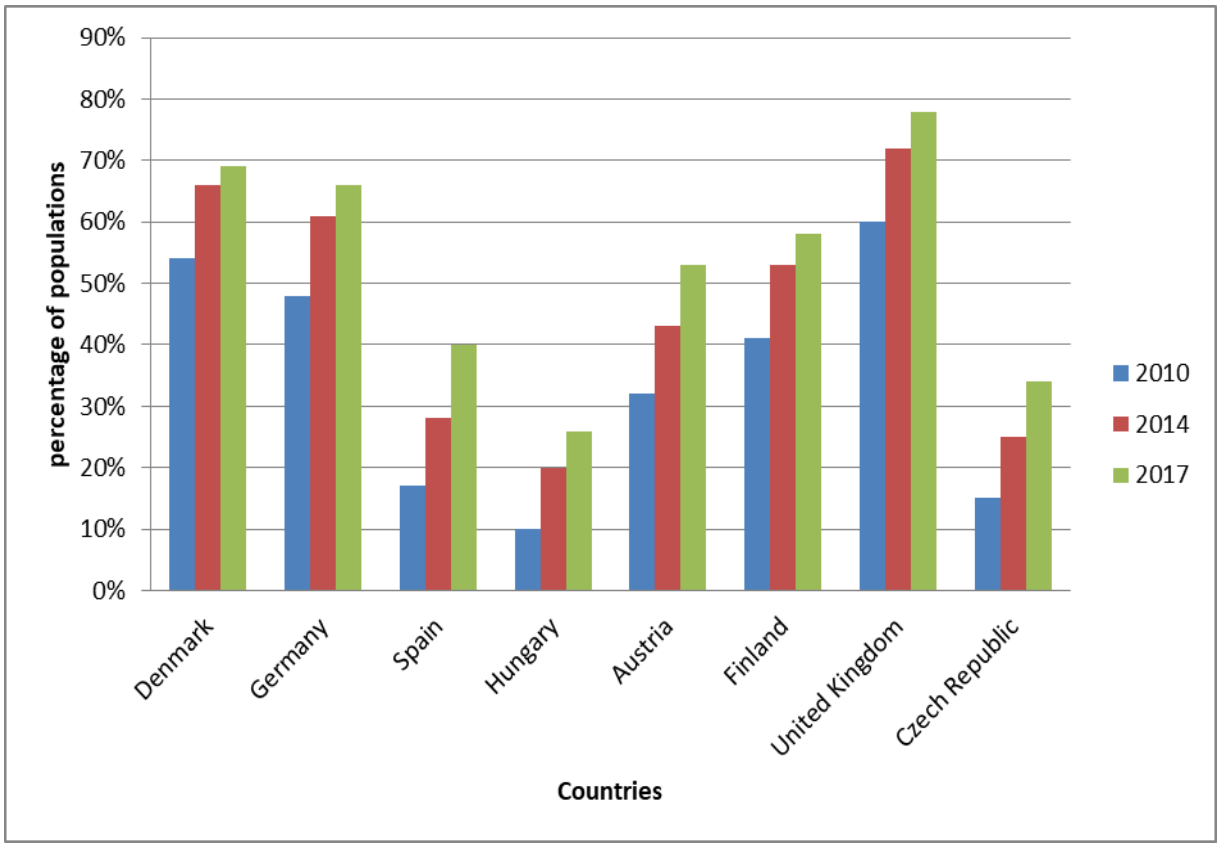

Figure 18: e-commerce transaction in selected countries

Source: own with data from Eurostat

4.2 E-Government

From figure 19 above, E-Government refers to the use of information and communication technologies (ICTs) devices such as computers and the internet to enhance public sector organisation and activities. According to (Sandoval-Almazan & Gil-Garcia, 2012) it consists of the digital communications between governments and their citizen (G2C), between governments and other government agencies (G2G), between government and employees (G2E), and between government and e-businesses (G2B). I compared the percentages of citizens that used the internet to interact with public officials in the selected countries. And the results are shown in the figure below.

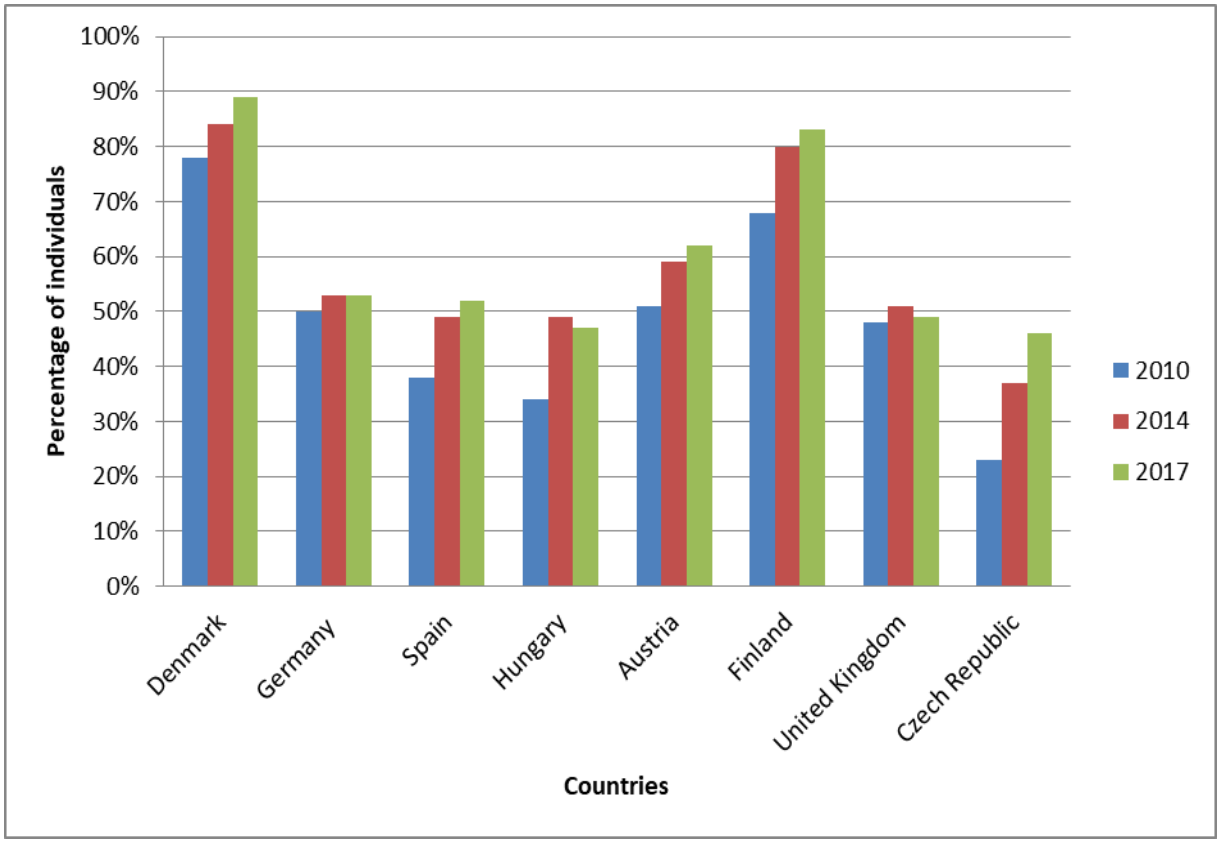

Figure 19: percentage of individuals interacting with public authorities online

Source: own with data from Eurostat

From figure 20 above, Denmark has the highest share of citizens interacting with public officials using ICT mediums. The share of the population that communicated with public officials was 78 % in 2010, this rose to 84 % in 2014 and finally to 89 % in 2017. In the United Kingdom, less than 50 % of Britons didn't use the internet to contact their public authorities. The results for the Czech Republic, Hungary and Spain, demonstrated that bellow 50 % of the population used ICT to communicate with their authorities.

4.3 Internet Cost across Europe

Since the internet is the backbone of the smart-cities concept this section of this dissertation provides a general overview of internet prices. From figure 21 below, it can be seen that the country with the most expensive internet prices is Iceland, 60Mbps cost 50.97 €, Followed by Ireland 45.47 €, Switzerland 45.37 €. Countries like Russia and Ukraine have the lowest prices of internet in Europe.

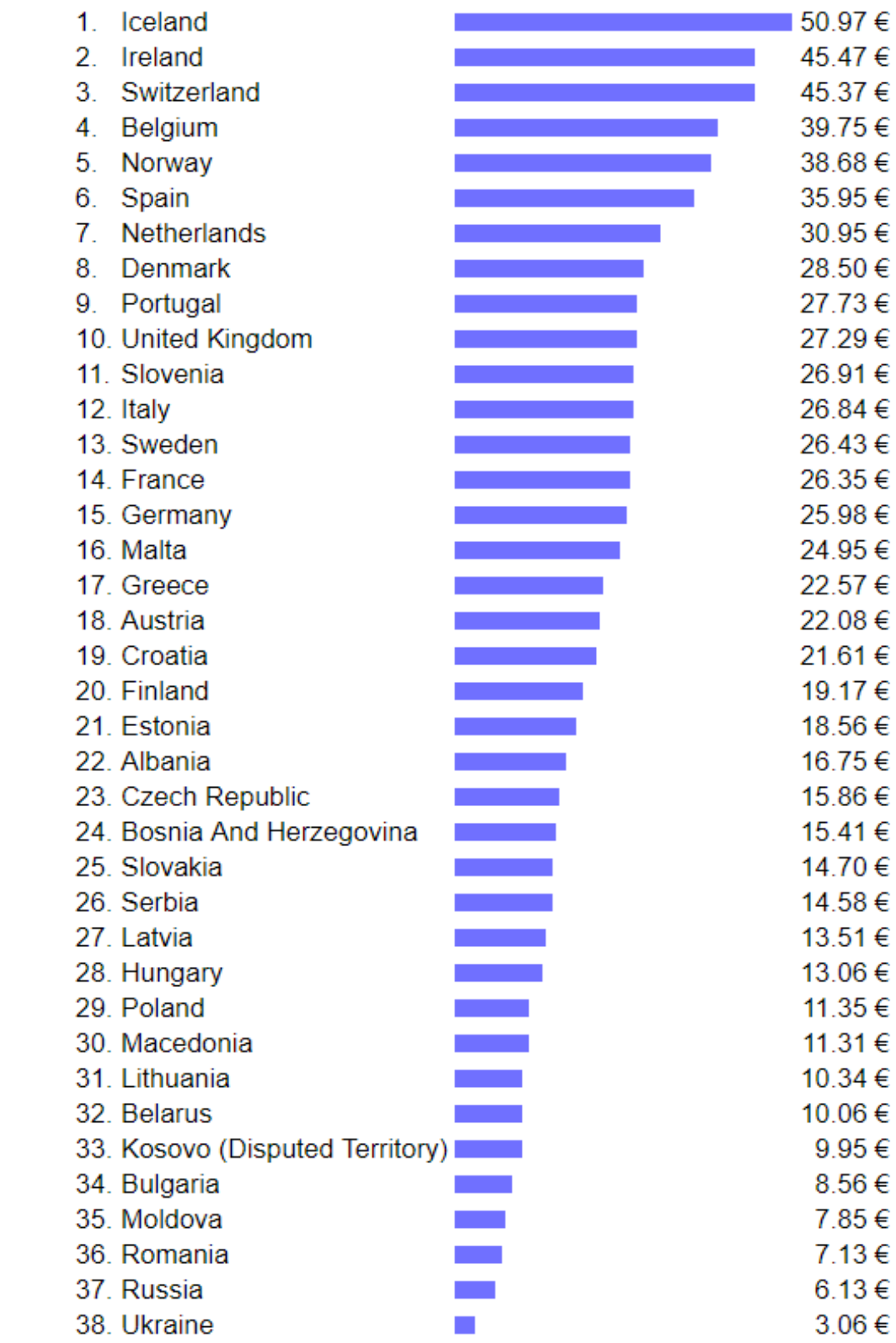

Figure 20: Average monthly internet prices across Europe

Source: Numbeo

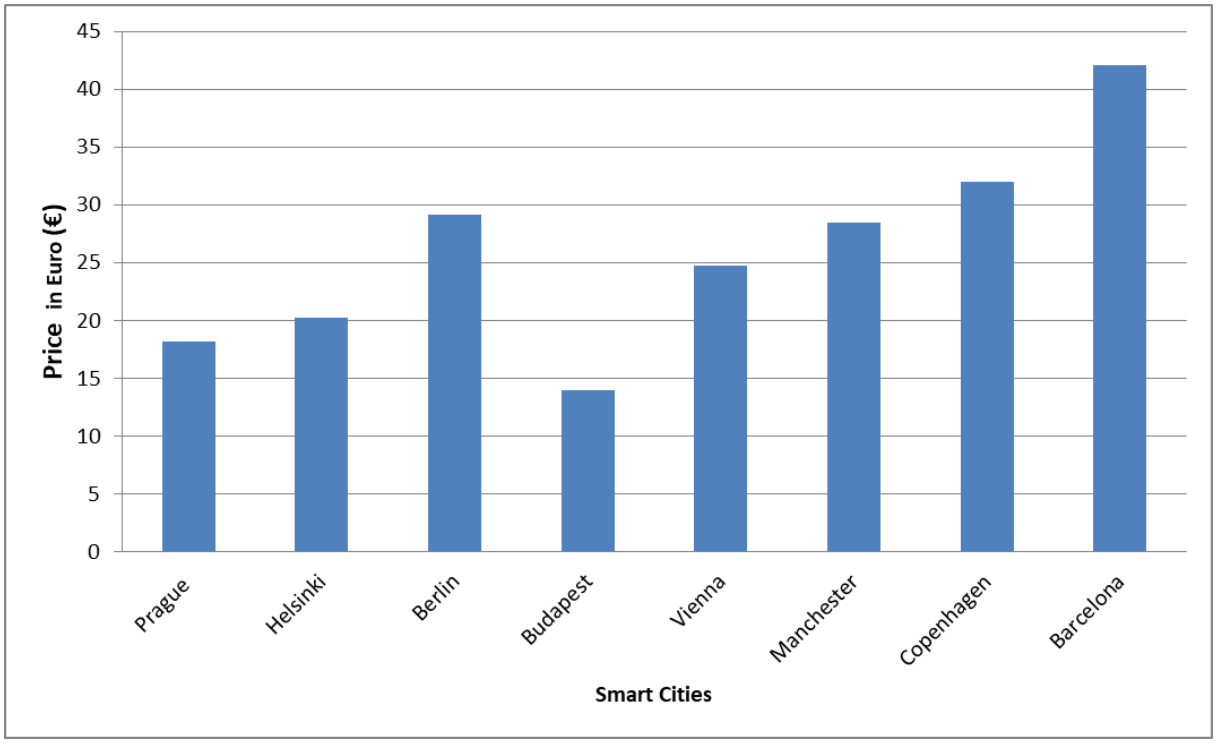

Figure 21: Average internet cost in focused smart cities

Source: own with data from Numbeo.com

From figure 22 above, Spain has the highest internet usage with a cost of 35.95 € than that of Czech Republic and Hungary with a cost of 16 and 13.06€ respectively within a month.

4.4 Device Connectivity

Device connectivity is very important in smart city development because the whole concept is built around IoT devices. Internet connection allows devices such as sensors that are embedded into IoT devices to collect and gather useful data that can be examined to gain relevant insights about city events like parking spaces etc. Devices that enable internet connection allow city systems to exchange and manage information rapidly.

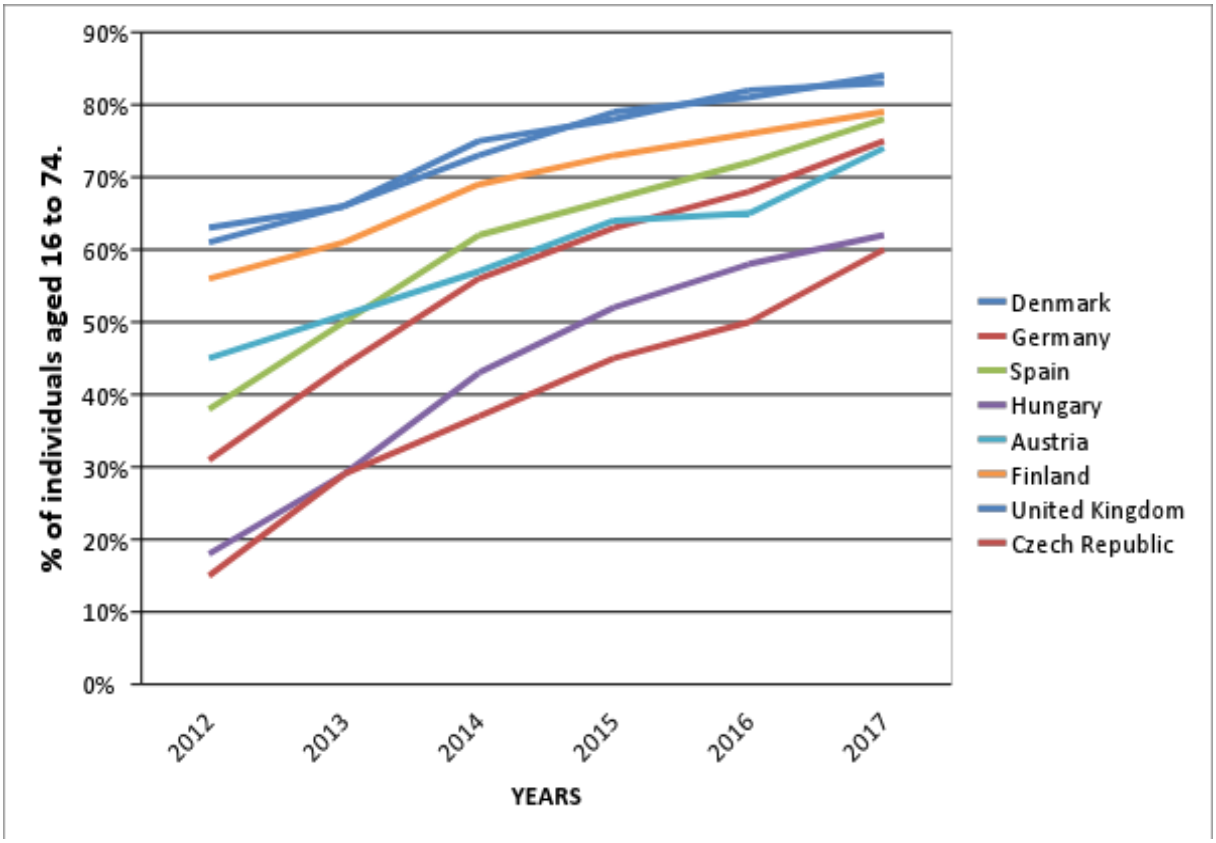

Figure 22: Individuals using mobile devices to access the internet on the move

Source: own with data from Eurostat

Among the selected countries, Hungary had the lowest number of people aged between 16 to 74 using mobile devices to connect to the internet in 2012, although this increased in subsequent years, it is still sagged behind countries like Finland, Spain, United kingdom etc. Denmark and the United Kingdom had the highest number of people aged between 16 and 74 connecting to the internet using a mobile device. In 2012, both countries had over 60 % of this age category using the internet, this further increased to over 80 % in the year 2017.

5 SUMMARY, BEST PRACTICE AND RECOMMENDATION

This chapter provides a summary of the major findings and conclusions that can be drawn from these findings. In addition to the above mentioned, it ends with recommendations that might be useful to policy makers, governments, city authorities and citizens on how best to promote city development to make them smart oriented. It is imperative that regulatory authorities provide solid new regulatory frameworks that are updated for the digital future and allow cities to grasp the potentials of ICT. The main aim of this dissertation was to evaluate selected smart cities case studies with focus on ICT penetration.

First of all I begun by introducing the concept of smart cities and this was covered in the first two theoretical chapters. I have unearth that future cities are aiming to be sustainable and smart communities surviving within the knowledge-based and global information economies and playing pivotal roles in expanding urban competitiveness, producing mutual benefits for the regional and the national economy as a whole.

Technological progress is driving cities as engines of urban growth and regional development. Technology is regarded as the key driver and core components of a smart city development. A smart city ensures quality of life because of the links between growth, productivity, and human capital. Smart city is propelled by technologies to advance competitiveness leading to sustainable future through the combination of infrastructures, people, energy, businesses, technologies and consumption.

Smart cities utilize strategic ICTs to provide innovative support to the management of public services to better the quality of lives of residents, to promote coherent sustainable development, technological and environmental improvement.
Smart cities are characterised as cities that makes efficient use of ICT and digital technologies to benefit citizens and businesses. The European Union knowing the importance of smart cities has heavily invested in innovation and ICT research to simultaneously improve the quality of life of EU citizens and making cities sustainable by the year 2020.

Similarly I have been able to demonstrate that ICT infrastructure plays an essential and key role in smart city development. ICT infrastructure forms the foundation that supports smart

city organization. ICT infrastructure comprises of the physical and fundamental resources that sustain the processing, flow, storage, and analysis of data. Every city aiming to be smarter needs to make sure that communications programs are well-established and accessible. Access to an up-to-dated basic infrastructure for data communications such as mobile networks, fixed networks, and networks for IoT will be crucial for cities aiming to be smart. The importance of access to suitable broadband infrastructure promotes city development and innovation.

Secondarily I focus on the number of people who use mobile devices such as mobile phones (smart phone), portable computer (tablet, laptop,) or other mobile device such as PDA, e-book reader etc. to connect to the internet either via mobile or wireless connection. It is worth noting that in all the selected countries, the number of people aged between 16 and 74 using the internet increased. The United Kingdom and Denmark had over 80 % of this age group using the internet. Hungary had the lowest rate of connection for this age group (about 60 %).

Thirdly I compared the extent of internet penetration in the selected smart cities, but due to data constraint, the analysis used national data instead of selected cities' due to the difficulty in getting data. Internet Penetration here simply refers to the total percentage of a country's population that uses the Internet. I have been able to prove that internet use in the selected countries was very high with over 80 % of the population use the internet for various reasons. Denmark and the United Kingdom had over 90 % of inhabitants using the internet.

Also with regards to fixed broadband subscription, it was seen that the total number of subscriptions to broadband technologies with download speeds of 256 kbit/s or more using mediums such as fibre-to-the-home, DSL, cable modem, and other fixed technologies was very high in Denmark, Germany, Austria, Spain and the Czech Republic had most connection. It was seen that over 90 % used the internet through fixed broadband.

Another aspect where the internet influenced life in these selected countries was through E-commerce i.e. transactions carried out electronically using the Internet. The United Kingdom had the highest share of citizens conducting their transactions online for the selected countries. About 60 % of Britons purchased a good or service online in 2010, 72 % in 2014 and 78 % in 2017. Conversely just 10 % of Hungarians bought something electronically in 2010, this increased to 20 % in 2014 and finally to 26 % in the year 2017.

With regards to e-government Denmark has the highest share of citizens interacting with public officials using ICT mediums. The share of the population that communicated with

public officials was 89 % in 2017. In the United Kingdom, Czech Republic, Hungary and Spain, less than 50 % of citizens used the internet to contact their public authorities.

Some of the best practices shaping these selected smart cities are summarized in the table 9 below

Table 6: summaries and best practice of smart cities

Cities	|best practice	Component of smart city
Manchester	Use of ICT to cut down crime, better health, transportation, environment and education	Economy, living, environment, mobility, people, governance
Barcelona	Smart grid and solar hot water ordinance	Smart governance, smart environment, smart economy, smart living
	Smart routing, sensors and tracking	Mobility, Environment
	Street lightening with sensors	Smart environment, smart economy
	Integrated transport solution	Smart Mobility
	Online government portal	Smart governance
Copenhagen	Smart cycling	Smart mobility
	Smart open service platform	Smart governance
Helsinki	Integrated multi-modal transport	Smart mobility
	Smart open service platform	Smart governance
Vienna	Mobility solution	Smart mobility
Budapest	Network traffic management	Smart mobility, smart

	Networking intelligent cities for energy efficiency	environment Smart energy, smart mobility
Berlin	Citizen participation platform Electromobility Micro smart grid Innovationszentrum Connected Living	Smart governance Smart mobility Smart economy, environment Smart living
Praha	user-friendly web application (IDOS, DPP)	Smart mobility, Smart governance

Source: own with data from Eurostat

5.1 Recommendations

- This dissertation has provided a detailed look at the concept of smart cities across Europe and has proven that most Eastern European cities are now piloting the smart cities concept. One example of such cities is Prague. Therefore this thesis recommends that Prague which has been classified as a re-invented capital characterized by above-average economic performance, balloon growth of GDP and added value and competitiveness. So in order for Prague to advance from the re-invented capital status to a fully-fledged smart city measures need to be put in place to strengthen innovation, creativity and city infrastructure to interconnect all areas and sectors of the economy to benefit social interactions and synergies.

- Secondarily the smart city initiative is an expensive venture, so city authorities and planners need to develop strategies and initiatives that are (SMART) meaning their intended objectives need to be specific, measurable, achievable, realistic, and time-dependent objectives, and must be aligned with city development strategies and also the Europe 2020 targets. The initiatives must contain attainable business plan, clear governance measures and a strong assessment and performance measurement strategy.

- Thirdly, all cities aiming to go smarter must need to be secured in terms of IoT security. This calls for stringent governance policies on data protection for both public and private and using the individual internet.
- Lastly citizens need to be engaged for better governance. Participatory governance enhances the democratic engagement of citizens to increase citizen participation in government policies. Participatory governance involves seeking ideas from citizens for the improvement of cities. Participatory governance enhances citizen-government interaction which further advances the concept of democracy as well as service delivery and social inclusiveness

6 CONCLUSION

The aim of this thesis was to evaluate some smart selected smart cities across Europe with focus on ICT and internet penetration and how it influences all the various smart city components. This dissertation used the comparative studies approach to compare the selected smart cities. The comparison among the carefully selected smart city projects provided this study with detailed understanding of some key initiatives taken to make these cities smarter and provide understandings of some lessons and policy implications that can be emulated by other cities aiming to be smarter cities.

I undiscovered that most of the smart cities have projects that were strongly focused on the environment and mobility component. All the cities understudy (Prague, Helsinki, Manchester, Barcelona, Vienna, Berlin, Copenhagen and Budapest) all aimed to be energy efficient and sustainable as a means of combating the rising trend of climate change and its disastrous effects on the economy and individuals.

Emerging technologies such as social media and other mobile communication now provides new opportunities for people in these cities to engage public officials and people in the city. I undiscovered that in Denmark about 89 % of the citizens engaged public officials using the internet. While in the United Kingdom, Czech Republic, Hungary and Spain had less than 50 % of citizens using the internet to contact their public authorities. These internal and external smart ways of governance influences greater participation and collective decision making.

6.1 Research Limitations

The focus of this dissertation was on the city level analysis rather than the national level. It was very difficult to get data on the various smart city initiates. This hindered the comparisons because in some cases I was forced to use national data which to me didn’t provide a true reflection of issues pertaining to the city.

6.2 Recommendations for Future Research

1. I also found out that most of the compared cities were at different stages of the smart city project implementation. So comparing cities that had long implanted their projects with those at the beginning stages were bound to lead to some deficiencies. Further studies to compare these cites based on the same year of commencement, size, similar sources of finance will bring out a better comparison.
2. Funding sources for these projects will sustain it. So further research on all the various sources of finance available for funding smart cities across Europe will help other cities to identify them and contact them for assistance.

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