Ph.D. Dissertation in Engineering

Studies on Empirical Investigation of Success Factors for Smart City Implementation:

Citizen's Adoption and Intellectual Capital Approach

February 2019

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이 논문을 공학박사 학위논문으로 제출함

2019년 2월

서울대학교 대학원

협동과정 기술경영경제정책전공

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Tanzeel Murtaza 의 공학박사학위논문을 인준함

2019년 2월

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Dedicated to my beloved parents, beautiful wife, and lovely daughter

Abstract

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The emergence of knowledge intensive industries gave rise to the issue of intellectual capital management which is used as an instrument to identify and measure the hidden sources of value creation at the firm, regional and national level. Knowledge-intensive companies are rated much higher than their book value suggests, and thus need to identify the intangible valuables of the company for the improvement and sustainability of their learning and capitalization system. Intellectual capital components are the key resources that can be leveraged for smart city development which intends to use information and communication technologies in order to bring efficiency and sustainability to the urban functions. The role of intellectual capital components in smart city implementation needs to be studied due to the fact that attributes of intellectual capital components would

have a distinguished impact on value creation and the increase in productivity and performance.

Despite the existence of a significant number of literatures on intellectual capital, the role of its components in the success of smart city implementation has not been examined. This research aims to investigate the role of intellectual capital components towards smart city success using an analysis of experts' preferences for human capital and structural capital. The research also includes the demand-side perspective towards smart city information services characteristics that influences the adoption decision. The analysis is performed using two methodologies: Analytics Hierarchy Process (AHP) for human capital and structural capital and discrete choice analysis using a mixed logit model for the adoption of smart city information services.

The first study employs a multidimensional approach to the development of a model for human capital using individual-level characteristics and the collective behavior. The identification of the sources of value in human capital is critical to the success of smart city implementations as these capabilities can be leveraged and upgraded to improve productivity and performance. Human capital components have been categorized into personal qualifications, personal traits, culture and social factors. The findings reveal that the most important category is personal qualifications followed by culture. Moreover, the overall priority weights estimation shows that the existence of domain-specific tacit knowledge gained through experience, the multi-disciplinary scope of education and the density of R&D personnel are the top-three ranked attributes of human capital towards smart city success.

The study on the structural capital examined 24 smart city cases across the globe to identify the structural capital elements valuable in the smart city development

process. The different orchestration of these structural capital elements can influence the outcome of the development process and its impact on the efficiency of the urban systems. The identified structural capital elements have been categorized into process, relational and infrastructural dimensions. The findings reveal that the infrastructural dimension comprising communication and information system is most critical towards the smart city success, followed by the process category with the most dominant component of policy. The overall ranking of these elements suggest that the decision makers need to focus on city-level policies and the development and enforcement of procedures for innovation generation.

Finally, the citizens' preferences analysis was performed for the case of Islamabad city in Pakistan which is at the early stage of smart city development and can benefit from a better understanding of the demand-side perspective. The characteristics of smart city information services considered in the study comprise language, access mode, service ownership, interoperability and security. Willingness-to-pay was used to observe the price sensitivity of the end users' choices. The findings reveal that citizens in Islamabad have a higher utility towards the use of the English language, a mobile access mode and a high level of security.

In conclusion, the study provides guidelines for policy makers who are concerned with the early stage of smart city development. The demand-side study of Islamabad city provides valuable insights in to existing trends that affect the rapid adoption of smart city services.

Keywords: Smart Cities, Intellectual Capital, Human Capital, Structural Capital, Information Services

Student Number: 2016-30759

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Chapter 1 Introduction

1.1 Overview

While we are transitioning towards the fourth industrial revolution, the knowledge intensive companies in information and communication technologies (ICTs) are leading the global market. Apart from financial competitiveness, the convergence of technologies and the penetration of ICTs into other disciplines increases the importance of the role of ICT and knowledge intensive firms in every aspect of today's life, including personal and professional matters. Despite a significant part of the global population still being offline, the diffusion of the internet has experienced rapid growth. This led to new opportunities for inclusion, increased efficiency and total factor productivity. Alongside its applications in industry, the use of ICTs by governments with the aim of better governance is being practiced across the developed world and also the adoption of e-government in developing countries is steadily increasing. The topic of intellectual capital (IC) has been a focus of research for over a decade to pin down the intangible sources of value creation in firms and measure their monetary value. The necessity for an investigation of intellectual capital is supported by the companies' desire to compensate the inabilities of traditional accounting systems to measure the value and impact of the intangible assets present in the form of skills, knowledge, processes and the

relationships within and outside the firm. In order to identify, leverage, renew and maximize the value of intellectual capital, suitable measurement and reporting models need to be developed and utilized at the micro, meso, and macro levels.

The difference between the book value and market value is known as Tobin's q ratio (Bontis, 1998) and for knowledge intensive industries was found to be much higher than that of manufacturing industries. This extra value added is related to the concentration of hidden value sources within the organization that are not depicted in the accounting books, and is known as intellectual capital. Intellectual capital is defined as the sum of human capital and structural capital (Edvinsson & Sullivan, 1996; Tovstiga & Tulugurova, 2009). Human capital contains the qualification, competencies and other attributes of the human workforce (Cote & Healy, 2001), whereas structural capital comprises process, infrastructure and relational dimensions (Lin & Edvinsson, 2010; Dameri, Ricciardi & D'Auria, 2014). Management of intellectual capital helps in capturing and codification of the information, acquisition of new competencies and re-engineering of the business processes in order to obtain a competitive advantage (Bontis, 1998). The value of knowledge intensive industries depends upon the amount of knowledge present in the firm in tacit (human resources) and codified form (databases, patents, copyrights). As these firms rely on commercialization of knowledge to generate revenue, the

human resources are crucial assets of the firm as they are movable and contain knowledge which is yet to be codified.

The emergence of cities as the locus of innovation and growth has triggered the inflow of workforce from rural areas seeking potential employment and business opportunities, eventually raising the urban population. This resulted in urban competitiveness and sustainability becoming prime objectives for policy makers, pushing them to develop strategies and actions plans to achieve these goals. By 2050, more than 60% of the global population is estimated to be living in urban areas. The increased urbanization inspires the use of technologies to solve urban management problems to ensure the efficiency of processes and sustainability of the city functions. The concept of smart city utilizes the advancement in technologies especially information and communication technologies to improve the efficiency of urban services and systems (Anthopoulos & Fitsilis, 2015) such as transportation, safety and disaster management, environment, healthcare, education and economy etc. through a transformation of cities' traditional infrastructure into modern digitally equipped integrated systems (Batty et al. 2012). High speed communication networks, robust and flexible software programs and sensing technologies lay the foundation for the development of smart cities. Internet of Thing (IoT) aims to connect physical devices to the communication infrastructure, thus converting them into a source or destination for data and information.

The use of IoT to build smart cites will eventually create a virtual replica of the city. The creation of a virtual replica of the physical infrastructure in the city through digitization generates valuable data which can be shared among collaborating entities. This data can be analyzed for making better decisions and quick fixing of problems in the respective systems (Nam & Pardo, 2011a). The conception of open data aids utilization of potential for open innovation from the community, entrepreneurs and startups (Chan, 2013). The new services can be developed by businesses and the citizens using the open data, further contributing to the smart city development objectives. The accomplishment of smart city development thus requires the concentration of the creative human capital to make the cities smart through continual innovation.

The idea of smart city development has recently gained much popularity across the globe as depicted by the number of initiatives taken globally. Cities around the world are already using technology to realize the notions of smart mobility, smart economy, smart education, smart healthcare and smart living (Hojer & Wangel, 2015). This is due to the emergence of technologies like IoT, cloud computing, data analytics tools and high speed communication systems. With the capabilities of sensing data from city infrastructure through IoT, and transporting it over high speed communication links to the cloud system offering flexible storage capacity, smart cities development offers immense opportunities for solving

community issues like traffic congestion avoidance, crime control, incident management etc. The ultimate objective is to ensure the sustainability of the city systems through the use of information and communication technologies. The International Telecommunication Union (ITU) has started using the nomenclature of smart and sustainable cities, highlighting the sustainability of a city as the most important success factor for the implementation of smart cities.

The integration of ICTs into the city management functions to improve processes, services delivery, and the quality of life of the citizens is a major topic of interest for researchers, city managers and mayors. The smart city categories include smart people, smart economy, smart education, smart environment, smart energy, smart transportation (Nam & Pardo, 2011a). While different definitions of the smart city have been observed across literature where the nomenclature of digital city, ubiquitous city, intelligent city are used, the core objective remained constant, i.e. the improved quality of life and services for the citizens. Another constant amongst the different approaches to improve the city management functions is the extensive use of ICTs. While the increased instrumentation through the use of sensors and IoT helps to create a virtual replica of the already isolated systems, the hyper connectivity of the different systems generates new opportunities for innovation and development of new applications. Thus, the success of smart city development highly depends on the identification

of intangible sources of value so that these elements of intellectual capital can be captured, codified, improved and monetized if needed.

Rapid diffusion of information and communication technologies and the emergence of knowledge intensive industries have driven the investigation of human capital measurements to identify the value sources in workforce capabilities. Investment in human capital development has been realized globally as a key factor for an increase in growth, productivity, and acquisition of competitive advantage. The role of human capital in smart city implementations is critical due to their integral objective to use ICTs in providing cross-sector solutions to the issues in city operations. The role of human capital has been established as a production element for city efficiency, growth and sustainability (Berry & Glaeser, 2005; Caragliu, Del Bo & Nijkamp, 2011). However, in contrast to previous studies, the complex nature of smart city development and the hyper connectivity of the subsystems require a comprehensive investigation of human capital ingredients using a multidimensional approach to identify their relative importance towards smart city development. Existing literature on the role of human capital as a production element mostly employs standard indicators such as education attainment, expenditure on R&D/education (Asteriou & Agiomirgianakis, 2001), number of graduates etc. A detailed investigation of human capital is needed to identify its components which are important towards achieving efficiency and sustainability in city

functions by applying technological solutions, which is seen as the core objective of smart cities development. A ranking of the human capital attributes allows identifying the focal areas where the attention of policy makers and investment is required to upgrade the human capital attributes. This leads to the first research question: *What are the critical elements of human capital that influence smart city implementation success*?

Despite the existence of literature on intellectual capital and human capital, the effect of structural capital on the success of smart city implementations has not been widely studied. There have been several studies on smart city development models, objectives (Abdoullaev, 2011), performance measurement (Lombardi, Giordano, Farouh, & Yousef, 2012) and management, however, the role of structural capital is yet to be explored. Dameri (2012) argues that the poorly rooted smart city movement in management studies correlates to the unsatisfactory outcomes of smart city investments. He is of the view that the components of intellectual capital are the key resource categories that can be leveraged for smart city success (Dameri & Ricciardi, 2015). While it is widely accepted that intellectual capital components are key value sources, the elements of these components would have variable value addition to smart city success. There could be multiple alternatives for processes, establishment of relationship amongst stakeholders, infrastructure deployment and difference orchestrations of these resources may result in different value

generation (Komninos, 2015). For example, the role and responsibilities of smart city authority would vary based on the employed development and management approach. Similarly, the management approach can impact the overall efficiency of the system, an example of which is the barrier to integration in the bottom-up development approach. It mandates the investigation of the relative importance of the structural capital attributes establishing the second research question as: *What are the critical elements of structural capital that influence smart city implementation success?* Organizations with strong structural capital will provide an environment which is favorable to utilize the fullest potential of the workforce, eventually increasing the innovation performance and productivity (Wu, Chang, & Chen, 2008). While the success of smart cities is highly dependent on the creative and innovative human capital, the presence of strong structural capital is required to provide a suitable environment for the human capital.

Citizens play a critical role in the development of smart cities as they are both the consumers and producers of information. Although many initiatives in smart city engage citizens in the decision making process, making it a collaborative effort, it is important to consider the demand side perspective to bridge the gap between the end users' expectations and the planners and policy makers' strategy. An unmatched scenario, where citizens' preferences are not met can hinder the adoption of the smart city

services. Researchers have identified the impact of technology attributes like security on the decision of end users towards the adoption of service (Pérez-Hernández & Sánchez-Mangas, 2011; Sin, Choy, Lin, & Cyril, 2010). Similarly, the choice of the language used in smart city services can impact the adoption rate of these services (Ninsiima, 2015; Gudmundsdóttir, 2010). It is therefore mandatory to analyze the demand side preferences towards the characteristics of the smart city information services which can impact the adoption decision by the citizens. To provide the policy guidelines for Islamabad smart city development in Pakistan, a study was conducted targeting citizen's preferences in Islamabad in order to answer the question: *What are the characteristics of information services affecting the adoption decision of smart city services in Islamabad?*

1.2 Purpose of the Research

The traditional measurement methods and models are not fit to be applied to the investigation of the role of intellectual capital in smart cities due to the different objectives, structure of the components and the relationship amongst the stakeholders. While a firm depicts a strictly hierarchical structure, where the vision and strategy of the firm are defined to improve the financial success, the smart city development purpose differs from strictly financial objectives. The firm's identification of intellectual capital is driven by the need for an accounting system to estimate the missing

elements of the balance sheet, whereas the smart city intellectual capital identification would help in the successful implementation, management and improvement of the city systems needed for the improved quality of life for citizens. Therefore, this research intends to identify the elements of the intellectual capital components, i.e. human capital and structural capital, and their relative importance towards the success of smart city implementation. The study also considers the demand side perspective towards the information services characteristics in Pakistan, which is helpful in utility maximization for the end users eventually leading to an increased adoption of smart city services. This is highly important considering the fact that developing countries like Pakistan find it difficult to spend huge budget amounts from public funds on the development projects.

The first study of this dissertation identifies and ranks the critical determinants of human capital towards smart city success and infers corresponding policy implications. The improvements in critical areas of human capital development will fuel the smart city implementation progress. The study uses a prevalent multi-criteria decision making technique, Analytic Hierarchy Process (AHP), to obtain the priority weights of the human capital components based on the forced choice pairwise comparison through expert's opinion (Saaty, 1987). The attributes of human capital have been identified through an extensive literature

review and are categorized into personal qualifications, personal traits, culture and social factors. The outcome of this study highlights the critical human capital attributes, which can be used for policy and investment decisions related to the renewal and upgrade of the skills and capabilities of the workforce.

In the second part, important elements of structural capital are identified and ranked with respect to their contribution towards smart city success. Based on the experts' responses, this study attempts to identify the optimal structural arrangements for smart city development projects. The methodology applied in this case for obtaining the priority weights of the attributes is AHP. The components of structural capital have been identified through the examination of 24 case studies on smart city development initiatives and are categorized into process, relational and infrastructural dimensions. These categories include the approaches for development and operations, mode of relationships amongst the stake holder including citizens and participating organizations, and the parameters and methods related to the ICT infrastructure part of smart city. In a nutshell, the study highlights the critical structural capital components which can be useful in decision making for smart city implementations.

Finally, the demand side analysis includes the functionality neutral characteristics of importance to the end users in which the attributes and

their corresponding levels for the smart city information services are identified. Discrete choice analysis is used to obtain the end users' stated preferences towards the attributes; language, access mode, service ownership, interoperability amongst different applications and participating organizations, security of the systems and cost. The levels for these attributes are as follows: language of the services is Urdu or English, access mode can be either web app or native mobile app, service ownership is public sector, private sector or public private partnership, interoperability is technical, semantic or organizational, and security is basic level or high level. By using a mixed logit model, the study estimated the perceived utility of the end users towards these attributes. The cost factor uses willingness to pay to investigate the price sensitivity of the users' choices.

1.3 Contribution of the Research

Smart cities are a major topic of interest among governments, the private sector and researchers trying to come up with innovative solutions and the development of supporting technologies and policy frameworks. However, there is a lack of comprehensive studies investigating the impact of intellectual capital components on smart city development. The outcomes of this research contribute in different ways to bridging a gap in academic literature (Nam & Pardo, 2011; Kourtit & Nijkamp, 2012; Attwell, 2007) as well as to provide practical implications for policy makers.

First of all, this research fills a gap in academic literature on the role of intellectual capital components in smart cities by applying the decision making technique AHP to the human capital and structural capital elements. The multidimensional approach used to develop the model for human capital further extends work on human capital studies which traditionally used indictors related to either individual level characteristics or missing the overall cultural trend towards the entrepreneurship, and research which is vital to the smart city development. Despite the availability of theoretical literature which highlights the need for creative human capital for smart city development, an empirical investigation of the attributes of human capital was missing. This research is unique as it incorporates the extended view of human capital considering the individual level characteristics of the workforce as well as collective capabilities and attributes. Further, the structural capital contains different alternatives that can be used in the smart city implementation process. However, the different mix of these alternatives for structural attributes such as management approach, development method, would result in different levels of efficiency. However, literature still lacks the investigation of structural capital attributes in the context of smart city. The study on structural capital is based on the actual smart city implementations by examining the different approaches of structural arrangement used by the smart city projects. The

research thus provides a foundation for the future research in the structural aspect of smart city.

Second, the study provides policy implications and guidelines for decision makers working on or intending to initiate smart city projects. While ample expertise, knowledge and resources are available from the developed world to be utilized in developing countries, it is also important to investigate the local context, needs and the strength of the specific project. This study has involved experts from academia and industry working in different countries in order to obtain wide-ranging opinions. This is due to the fact that varying perspectives exist towards the smart city scope, architecture and the success factors. For example, Songdo uses a strictly centralized management and control architecture, whereas Singapore's model for a smart city is based on a decentralized approach giving autonomy to the specific organizations. These perceptions are captured from experts working in different countries in order to derive outcomes closely aligned to the common needs. It is due to the fact that the considered smart city definition has a strict urban focus targeting citizen centric services and the examined smart city cases align to the definition of smart city in this research, thus having a high overlap of the city level issues addressed under the smart city umbrella. Therefore, the findings of the study are of common interest to smart city planners focusing on a similar service spectrum.

Finally, the analysis of demand side preferences using discrete choice analysis is helpful in identifying the consumer's needs and priorities towards the characteristics of smart city information services. On one hand, it highlights the importance of the consumer preferences towards the adoption of smart city services making it an agenda item for the smart city planners. On the other hand, it provides policy guidelines for smart city services development and deployment in Islamabad, Pakistan based on the estimation of the end user's choices towards different attributes of information services in a smart city. The pre-development analysis of the consumers' needs ensures that the citizen's preferences are properly reflected in the end systems, thus increasing the adoption rate of the information services. The study also provides insights towards the variation of results based on the demographic characteristics of the citizens such as gender and education level.

1.4 Research Outline

This research focuses on the identification of the valuables affecting smart city implementations from both the experts' and end users' point of view. The expert's opinion was considered for the prioritization of human capital and structure capital elements with respect to their importance for the smart city implementation. Similarly, the citizens' preferences towards the demand side characteristics were analyzed to pin down the utility

maximizing attributes. The layout of the research is represented in Figure 1.1. The structure of this dissertation is as follows: Chapter 2 contains the literature review that includes information on smart cities and intellectual capital. The existing models for intellectual capital management and reporting are presented together with the concept, measurement methods and studies on human capital. This chapter also contains information on the smart cities case studies which were examined for the identification of the structural capital attributes. Chapter 3 is a study on the role of human capital attributes in smart city development. This chapter contains the development of the model, methodology used, survey design and the estimation of results. AHP is the technique used in this study for identifying critical human capital elements. Chapter 4 is a study on the structural capital role in smart city which also uses AHP for the ranking of structural capital attributes. Chapter 5 presents the demand side analysis targeting the citizens in Islamabad, Pakistan for their preferences towards the characteristics of smart city information services. This study uses the random utility theory and mixed logit model. Concluding, Chapter 6 discusses the empirical findings and the corresponding policy implications along with limitations of the presented research and recommendations for future research.

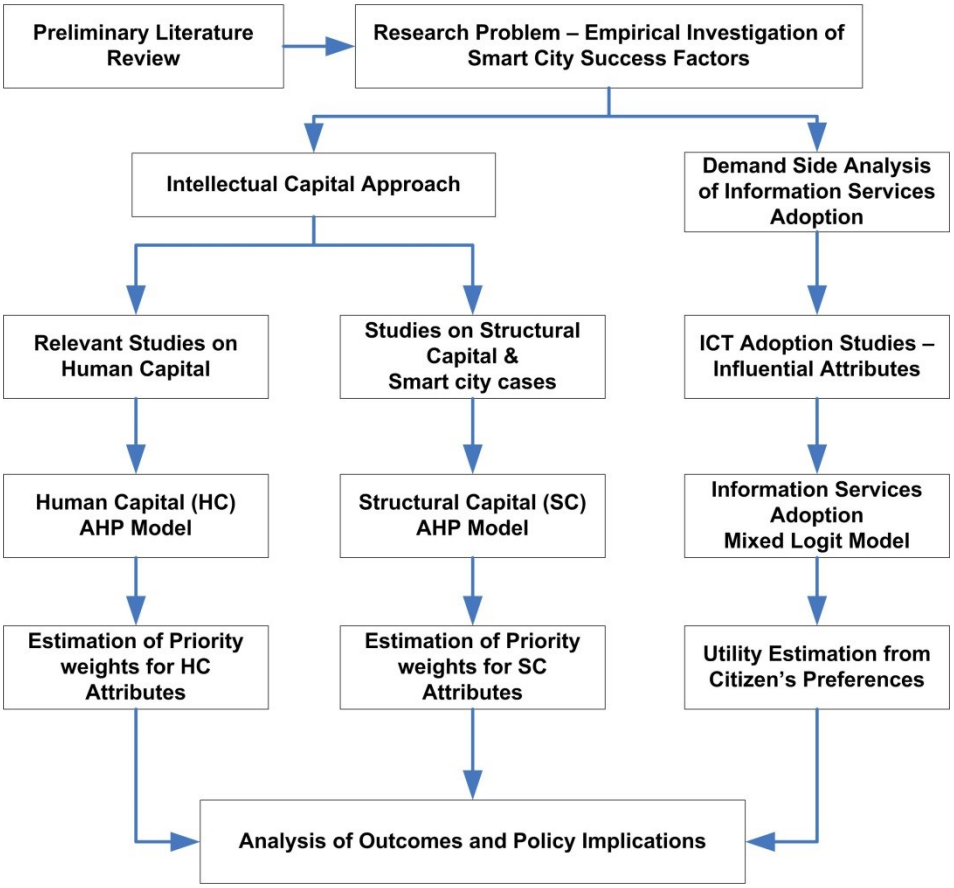

Figure 1.1 Research outline

Chapter 2 Literature Review

2.1 Smart Cities

The advancements in information and communication technology and the introduction of IoT drove the development of smart cities using technology to solve problems stemming from rapid urbanization. The concept of smart city comprises the use of technology to bring smartness in the areas of mobility, governance, people, education, environment (Letaifa, 2015) and economy (Zubizarreta, Seravalli, & Arrizabalaga, 2015). The use of technology for urban improvement has been discussed in literature under different names such as digital city (Mino, 1999), ubiquitous city and intelligent cities (Komninos, 2006). While a digital city integrates digital devices, sensors and actuators and information and communication technologies (ICTs) into the city infrastructure and processes, the inherent objective of a smart city is to bring efficiency, increase productivity and to ensure sustainability of the metropolitan services and systems by making proactive adjustments and informed decisions through the use of data. The integration of ICT helps to increase the interconnectedness of different systems in the city thus making it possible for decision makers to observe and automate cross sectorial perspectives. For example, Otto in Germany used a deep learning algorithm on previous purchase data and multiple

variables like weather condition, website searches, to predict the possible purchases of the buyers for the next week using 90% accuracy, thus placing an order accordingly. This kind of decision making would help in optimizing the supply line and eliminating the need for stock options. The process of smart city development is the outcome of continual innovation in improvement and development of new solutions, processes and services facilitating urban systems.

2.1.1 Smart City Definitions

Smart city research has progressed from two perspectives: The neo-evolutionary approach using the triple helix model of innovation relying on the government, industry and academia partnership in realizing the smart city (Leydesdorff & Deakin, 2011) and from a more concise implementation of ICT into urban management functions using technologies like IoT, cloud computing (Stratigea, Papadopoulou, & Panagiotopoulou, 2015), artificial intelligence and sensor networks. Definitions of smart cities vary across the literature, defining different types and scopes of the smart city development. Some of these definitions are given in Table 2.1.

Table 2.1 Smart city definitions

Definitions	References
"Integration of ICT in city management functions like mobility, waste management, emissions control, energy management, resource efficiency"	(Anthopoulos & Fitsilis, 2015)
"Transformation of traditional city infrastructure by modernizing through ICT and digital technologies for better management"	(Batty et al., 2012)
"A smart city infuses information into its physical infrastructure to improve conveniences, facilitate mobility, add efficiencies, conserve energy, improve the quality of air and water, identify problems and fix them quickly, recover rapidly from disasters, collect data to make better decisions, deploy resources effectively, and share data to enable collaboration across entities and domains."	(Nam & Pardo, 2011a)
"We believe a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance."	(Caragliu et al., 2011)
"The new intelligence of cities, resides in the increasingly effective combination of digital telecommunication networks (nerves), ubiquitously embedded intelligence (brains), sensors and tags (sensory organs) and software (knowledge and cognitive competence). This does not exist in isolation from other urban systems, or connected to them only through human intermediaries."	(Mitchel, 2007)
"A city that monitors and integrates conditions of all its critical	(Hall et al.,

infrastructure, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens"	2000)
"Smart cities are the result of knowledge-intensive and creative strategies aiming at enhancing the socio-economic, ecological, logistic and competitive performance of cities. Such smart cities are based on a promising mix of human capital (e.g. skilled labor force), infrastructural capital (e.g. high-tech communication facilities), social capital (e.g. intense and open network linkages) and entrepreneurial capital (e.g. creative and risk-taking business activities)."	(Kourtit & Nijkamp, 2012)
"Smart city as a high-tech intensive and advanced city that connects people, information and city elements using new technologies in order to create a sustainable, greener city, competitive and innovative commerce, and an increased life quality."	(Backici, 2013)
"Smart cities will take advantage of communications and sensor capabilities sewn into the cities' infrastructures to optimize electrical, transportation, and other logistical operations supporting daily life, thereby improving the quality of life for everyone."	(Chen, 2010)
"A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects."	(ITU, 2015)

In the presence of multiple varying definitions of the term smart cities, it is necessary to provide a definition of smart city in order to restrict and define the scope of this research. Therefore, in the further context of this research, smart city refers to the integration of ICT into urban services and functions like mobility, citizen safety, disaster recovery, utility management, environment protection and governance for the efficient utilization, management and sustainability of these systems.

It is clear from this definition, that smart city implementations require stake holders from different organizations, who might have earlier been working in isolation, to work in collaboration with each other

2.1.2 Smart City Components

Smart city components have been divided based on the infusion of ICT in different areas (Hojer & Wangel, 2015; Lombardi et al., 2012). These components include smart mobility, smart living, smart economy, smart governance, smart environment and smart people as shown in Figure 2.1 (Kapadia Associates [KA], 2015).

2.1.2.1 Smart Mobility

Smart mobility is the use of technologies to improve urban transport systems in terms of efficiency, accessibility and synchronization. Another

term, which is more often used, is intelligent transport systems. Variation of services exists across cities under the umbrella of smart mobility. Integration of geographic information system (GIS) into the transport system helps with the real-time tracking of vehicles, which can be made available to the commuters of public transport system (Kwon, Cho, Kim, Lee, & Lee, 2016; Toch, 2016). Traffic cameras can detect traffic rule violations with automated e-ticket generation. Commuters can plan multi-modal trips through the web or dedicated apps (Hwang & Choe, 2013; Wien, 2014) and can purchase the ticket in advance.

Smart mobility along with providing convenience to the citizens and increasing their quality of life also provides valuable traffic information about the usage pattern of the transport system to city planners and managers. This information can further be used for optimal scheduling, congestion avoidance and identification of necessary upgrades to the transportation system. Parking management systems help drivers find parking spots (Lee, Kwon, Cho, Kim, & Lee, 2016b) by checking the availability through an application program which helps to save time and fuel costs.

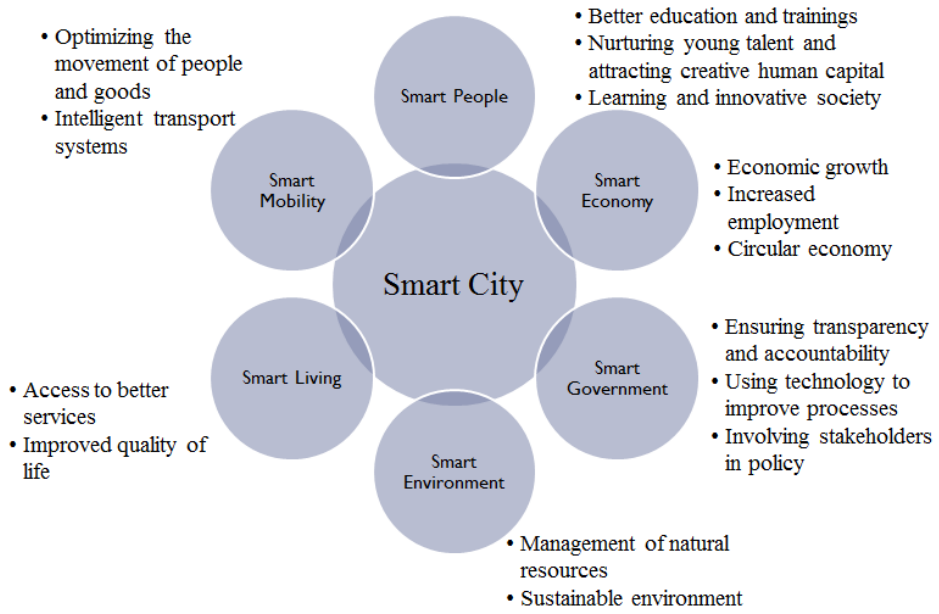

Figure 2.1 Smart city components

2.1.2.2 Smart Living

The concept of smart living in the smart city overlaps with many other categories with the focus on the use of digital technologies in day-to-day life. Other terminologies used under this umbrella category are smart homes and smart buildings, where the use of ICT brings automation to the service management and provisioning at the building-level like access control, services monitoring, disaster notification etc (Kwon et al., 2016). Similarly, smart homes use technologies for connectivity of the household appliances to the network for remote monitoring and management. The initiatives under this component are purposed to improve the quality of life for citizens by providing better access to the services. Ensuring smart

living in the city also requires using technology and following all standards for the support for elderly and disabled citizens. While the concept of the smart home under the umbrella of smart living increases the quality of life, there have been concerns over the privacy of the users and their information, which could be misused in case of any data breach. Therefore, the competence level of the end users and the security of the systems are highly desirable prerequisites.

2.1.2.3 Smart Economy

The use of information and communication technologies helps to boost the economic productivity in the city. The concept of sharing economy with the use of technologies such as block chains enables efficient resource utilization (Sun, Yan, & Zhang, 2016). On one hand, the advent of two-sided online platforms bridged the gap between consumers and suppliers while creating new opportunities for business. On the other hand, the existing economic sector expanded their market with the use of e-commerce platforms and communication technologies. Emerging technologies such as block chain are ready to revolutionize the financial sector with the approach of decentralized management and smart contracts (Sun et al., 2016). The use of technology to realize the idea of circular economy, which reduces the waste to minimal levels by recycling the items used in the city, will bring economic benefits along with creating a

sustainable environment. In a nutshell, cities use technology for economic development through efficiency and innovation in order to create employment opportunities for the citizens which in turn increase the gross regional domestic product (GRDP) as well.

2.1.2.4 Smart Governance

Smart governance relates to the optimization of government processes using technology in order to facilitate citizens in a better way. The implementation of e-government has been practiced for some time now and is also making its way towards the underdeveloped countries. Use of technology helps in realizing the idea of open government by making the government functions transparent to citizens (Hwang & Choe, 2013). A transparent government will ensure the true democratic system where the government will be directly accountable to the citizens. Similarly, the engagement of citizens in the policy making has been made possible with the use of technology (Amar, 2016) where governments establish co-creation models or uses opinion polls to quickly get the citizens' response towards any issue. Smart governance ensures that the citizens are facilitated and provided with convenient services (City of Dallas, 2018) and the government can manage their processes and improve decision making capabilities.

2.1.2.5 Smart Environment

Environmental sustainability is one of the major global concerns for the decision makers, making it an important component of smart city development (Caragliu et al., 2011). In the urban context, environmental awareness and preservation greatly benefit from the use of information and communication technologies. Citizens can get information and alerts about the weather and environmental details such as air quality, which can help them to better plan their routines and prevent health issues. The use of technologies like IoT can make it possible to efficiently manage water resources through quick detection of faults in the distribution network (Liu & Peng, 2014). Waste management in many cities has been optimized using IoT in conjunction with GIS to receive alerts for waste collection (Arup, 2010). The measurement of environmental indicators helps the city managers to take appropriate actions, examples of which are alerts to citizens, discounts or free public transport to reduce private traffic in case of bad air quality.

2.1.2.6 Smart People

Smart cities require smart citizens to ensure the effectiveness of technologies in city management and development (Nam & Pardo, 2011a). The initiatives under this category include, but are not limited to, nurturing

young talent and attracting them towards emerging technologies, promoting entrepreneurial culture and training of citizens and officials for use of technology. Development of training programs and incubation centers help in achieving these goals to create a smart community which can make the best use of technology. The initiatives and incentives related to attracting an inflow of smart people into the city also help with the accumulation of the creative class of the society, which is capable of addressing the urban problems. The ethnic diversity of the city helps in accumulating creative human capital, which through the knowledge spill over in the society, increases the overall community intelligence.

2.1.3 Smart City Systems Architecture

In order to elaborate the overall implementation architecture of a smart city system, the study uses a modified form of the smart city conceptual model for planning assistance by Zygiaris (2013) to structure the different segments into layers. Using the smart city technical system architectures (Lee, Kwon, Cho, Kim, & Lee, 2016a; Lee et al., 2016b; Lee, Kwon, Cho, Kim, & Lee, 2016c; Schreiner, 2016; Kwon et al., 2016), the whole system can be arranged into four layers, i.e. instrumentation layer, interconnection layer, application layer and knowledge layer as depicted in Figure 2.2.

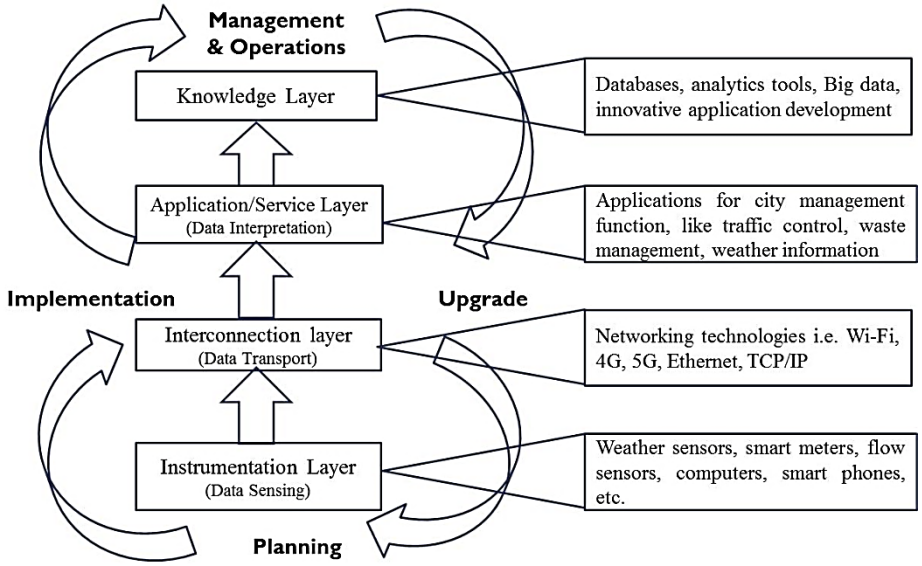

Figure 2.2 Smart city systems architecture

The instrumentation layer contains the end devices installed for data sensing/generation or information retrieval which may range from road side equipment's (RSE), smart phones, to the sensor installed for weather data collection, garbage monitoring, building control/monitoring, and computers. The interconnection layer connects the sensing and presentation devices to the network and transports data from these devices to and from the servers located in the cloud or in smart city operation centers. The application layer contains different applications/processes like traffic management, waste management, safety and security of the citizens that use data from the specific devices. Finally, the knowledge layer contains the integrated data from all the sources which can be used for decision making, and innovative application development. The cycle of planning, implementation,

operations and management, and upgrade covers the continuous improvement and innovation in the smart city systems to ensure its sustainability and effectiveness.

2.2 Intellectual Capital

ICT and knowledge intensive companies are rated much higher in the market than their traditional book value or the value of assets present in the firm would suggest. The Tobin's Q ratio, devised by the economist James Tobin, is the ratio of the market value of a firm on the stock exchange to the total value of its assets or book value (Bontis, 1998). The Tobin's Q ratio should be 1 in ideal conditions, meaning all assets and sources of value in the firm are documented and accounted. While manufacturing firms tend to have a Tobin's Q ratio of around 1, ICT and software firms and knowledge intensive firms have been observed to have much higher Tobin's Q values. During 1995, Microsoft's shares were valued at an average price of $70 when their so-called book value was just $7 (Sveiby, 1997b), resulting in a Q ratio of 10, which was not observed in the manufacturing sector. The difference between the market value and book value of the firm represents unaccounted assets due to which the company's market value is higher. A higher value of Tobin's Q ratio represents the increased presence of high intellectual capital in the firm. The identification of the intellectual capital elements is driven by the fact

that the accounting statistics do not predict the future performance of the firm. The different areas of presence of the intellectual capital in the firms are its employee's capabilities, motivations, the internal business processes, knowledge consolidation and relationship with the customers. The management of intellectual capital is vital to reduce the potential volatility of the firm's performance and the identification of the valuable information for codification, reengineering and enhancement of the capabilities contributing to a higher Q value. Kok (2007) gives the classification of measurement models for intellectual capital as follows:

Market capitalization method: The calculation of difference between stockholders' equity and market capitalization gives the financial value of intellectual capital. However, this method lacks the identification of the components contributing to the competitive financial advantage in the same industry.

Return on assets method: Annual earnings and the value of tangible assets are compared to the average of the specific industry. The value of intangible assets is then estimated through the above average earnings.

Direct intellectual capital method: Intellectual capital is estimated by identifying the various components and their specific indicators. This

model is helpful for analyzing the financial and non-financial aspects of intellectual capital.

Scorecard method – Different components of IC are identified and presented in the form of scorecards and graphs. While making the reporting format easier, it can also help align the input, processes and output to the organizational objectives.

2.2.1 Existing Studies on Intellectual Capital

Many researchers have investigated the issue of intellectual capital assessment and valuation and proposed methods and models that vary in scope from firm-level intellectual capital management to regional and national-level measurements. The following are some of these proposed models:

Balanced Score Card: In a study sponsored by Harvard Business School, Kaplan and Norton (1996) proposed the balanced scorecard model as a system of measurement for the intellectual capital intended to help efficient policy making and performance management of the firm. The output measures and the respective performance drivers in four different areas are measured and orchestrated in a cause and effect chain, thus identifying the valuable performance drivers. Vision and business strategy are converted into objectives in four different areas; customer, financial, internal business

processes and organizational learning and growth. Financial aspect covers the interests of the shareholders, while customer view is the organizational image suitable to the customer. Internal businesses processes identify the process efficiency required to satisfy the customers which in turn benefits the shareholders too. Finally, organizational learning and growth are areas where improvements help achieve the organizational objectives.

The cause and effect chain is the pillar of the balanced score card model which aligns the objectives and vision of the organization to the departmental actions and milestones transforming them into monetary benefits for the company and shareholders, while strengthening the link with the customers. For example, organizational learning leads to improved business processes offering better service to customers, resulting in timely payment and an increase of the customer base, which in turn increases the financial capital, hence satisfying the shareholders.

Skandia Navigator: The Skandia approach to intellectual capital modeling (Edvinsson & Malone, 1997) is based on the definition of intellectual capital comprising human capital and structural capital (Edvinsson, 1997; Edvinsson & Sullivan, 1996). Skandia Navigator has similarities with the balance score card approach, where its focus areas are financial, customers, process, human, and renewal and development. The indicators of the focus

areas in the reporting format help identify the source of values that could be capitalized and the areas for renewal and development through training.

Intangible Assets Monitor: Intangible assets monitor is a non-financial measurement system for intangible assets, which is based on the assumption that human actions create the internal and external structure of the organization (Sveiby, 1997a). The indicators are thus classified into three areas: the external structure, i.e. suppliers & customers, internal structure, i.e. organizational processes, and workforce competence. The approach to the measurement of the indicators for intellectual capital assessment is based on a matrix structure at the cross section of growth/renewal, efficiency, stability and internal structure, external structure and competences. For example, the investment in the information systems is the indicator at the cross section of growth/renewal and the internal structure.

The IC-dVAL Model: The IC-dVAL approach defines the indicators in the categories of resources, processes, assets and the outputs for strategic corporate performance management (Bounfour, 2003). The model attempts to measure the dynamic value of intellectual capital by integrating the earlier mentioned four dimensions. It also suggests an extension of the scheme to the national-level intellectual capital management in Europe. Asset indices are divided into human and structural capital indices.

National Intellectual capital Index: In contrast to the majority of literature on intellectual capital, which focuses on firm-level research, Bontis (2004) measures the intellectual capital at the national level to identify the country's invisible sources of growth. The focus areas of measurement are human capital, financial capital, market capital, renewal capital and process capital. The author demonstrates a positive association between intellectual capital and financial capital in the Arab countries.

The 4-Leaf Model: Based on the Skandia Navigator, the 4-Leaf Model (Leliaert, Candries, & Tilmans, 2003) introduces the concept of strategic alliance or partner capital along with human, structure and customer capital. The model suggests that an overlap exists amongst all these four sections and that IC can flow from one section to another. For example, a breakup of a strategic alliance may cost the firm some of its clients, thus reducing the customer capital. Similarly, the codification of knowledge within the firm changes the value creation source from human capital to structural capital.

Table 2.2 provides concise information about the models for the measurement of intellectual capital, along with their strengths and weaknesses.

Table 2.2 Intellectual capital models

Model	Structure	Strengths	Weaknesses
Balanced Score card (Kaplan & Norton, 1996)	Focus areas are financial, customer, internal business process, organizational learning having a cause and effect chain for linking areas	Considers the interrelations amongst the different stakeholders.	Weak assumption regarding cause and effect chain.
Skandia Navigator (Edvinsson & Malone, 1997)	Skandia reporting format for IC in human and structure capital to find value sources that could be used in balance sheet to check financial value	Numerical and financial nature Well suited for firm level analysis and reporting	Weak indicators selection Strictly financial thus ignoring nonfinancial traits
Intangible Assets Monitor (Sveiby, 1997a)	Human centric analysis of internal and external structure under the categories of organizational efficiency, stability and renewal	Human centric approach to IC measurement to identify the non-financial valuables	Indicators selection needs to be adapted among different business firms.
The IC-dVAL Model (Bounfour, 2003)	Indicators in the areas of resources, processes, assets and output for corporate performance management	Flexibility to apply at meso and macro level.	Overall performance indicator could be influenced by one area/indicator i.e. GDP for nation rich in natural resource.

National Intellectual Capital Index (Bontis, 2004)	IC measurement at country level along with the IC positive association towards financial capital.	Inclusive National level IC measurement in distinct subcomponents.	Specific to Arab countries. Not an organizational level instrument
The 4-Leaf Model (Leliaert et al., 2003)	Human, structure, customer, and partner capital along with the overlap amongst these areas.	Considers the flow of IC amongst components i.e. from human to structural capital	Not all aspects of the intellectual capital can be structuralized. i.e. Cognitive Skills

2.2.2 Intellectual Capital and Smart Cities

The intellectual capital evaluation models have strong and weak points; however they are not well suited for intellectual capital identification for smart cities due to the different underlying conditions. While most of the models focus on the intellectual capital evaluation at the firm level, where the inherent objective is to capitalize the intellectual capital of the firm and transform it into financial capital, smart city implementations are focused on the management of urban issues through the innovative use of ICTs. Smart city projects are mainly public sector driven, with only a very small proportion of them being executed in the form of a public private partnership, where the management and control mechanism differ from those applied in private sector firms. Further, the meso-level analysis for

the smart city implementation needs to consider the loosely coupled relationships amongst the stake holders in contrast to the strict hierarchical structure and orchestration of departments within firms.

The majority of studies are targeted at the firm level with the exception of the partner capital in the 4-Leaf Model, which also considers financial objectives. While the numerical and financial nature of the Skandia Navigator could be beneficial for adapting it to the firm-level performance management, the lack of relative importance amongst the focus areas needs to be compensated to identify the areas suitable for higher investment. Due to its balance sheet approach, the non-financial factors like organizational culture are ignored, which could lead to wrong calculations (Chen, Zhu & Yuan, 2004). Similarly, the assumption made in the Balanced Score Card Model about the cause and effect chain is not very strong, as a satisfied customer may not necessarily result in increased financial capital (Norreklit, 2000).

It is vital to the success of smart city implementations that the components of intellectual capital, which are the key resource categories for smart cities, are leveraged in a way that ensures the efficiency and sustainability of smart city systems (Dameri & Ricciardi, 2015). Doing this mandates realizing the fact that different elements of intellectual components would have a variable value addition and contribution towards smart city success

(Komninos, 2015). This problem becomes critical in the scenario where the input resources for smart city implementation are scarce and call for the highly efficient utilization of these resources for the development and renewal of intellectual capital.

2.2.3 Intellectual Capital Components

This research uses the intellectual capital definition from Edvinsson and Sullivan (1996) and Tovstiga and Tulugurova (2009), which divides intellectual capital into human capital and structural capital. Structural capital further comprises processes (organizational capital), physical and logical infrastructure (technological capital) and the relationships amongst the stake holders (relational capital) as shown in Figure 2.3.

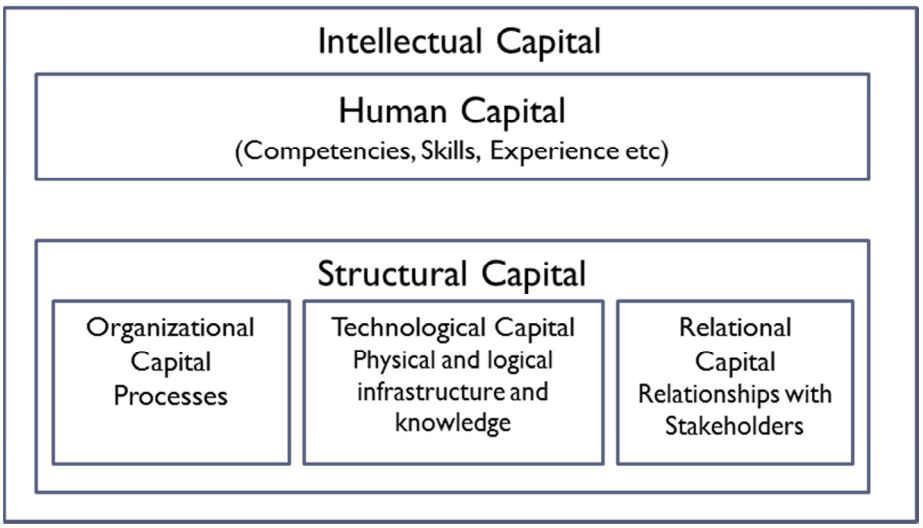

Figure 2.3 Intellectual capital components

2.2.3.1 Human Capital

Human capital has been discussed in economic perspectives with abilities of the human work force as an important component of national wealth alongside land and fixed capital (Schultz, 1961). However, the realization of the role of human capital in non-economic perspectives like social cohesion, individual's wellbeing and improved health status gave it widespread recognition. The proposed definition of human capital by the OECD (Cote & Healy, 2001) as comprising knowledge, skills, qualification, attitude and other individual's attributes has gained extensive acceptance, which lead to the investigation of its role towards productivity and innovation at the firm, city and regional and national level. The OECD's definition of human capital reveals its multifaceted nature having general and work related skills that can be both inborn capabilities like emotional intelligence and motivation or can be acquired through learning and experience like education or on-job training. The understanding and record of human resource capabilities can help in creating teams and organizational structures that aim to fully utilize the innovation potential and boost productivity (Koohborfardhaghighi & Altmann, 2017).

The complex nature of human capital as tangible, i.e., education level, education and R&D expenditure, and intangible assets such as motivation or job satisfaction adds to the difficulty for its measurement. The traditional

approaches for the measurement of human capital are categorized into output-based, cost-based, and income-based methods (Kwon, 2009). Output-based methods (Barro, 2001; Asterious & Agiomirgianakis, 2001) use indicators such as school enrolment rate, number of graduates, tertiary level education or the accumulated years of schooling at the employable age as measurements of human capital. The cost-based methods (Schultz, 1961) involve the investment or cost incurred during the development of human capital, e.g., education or training expenditure by the individuals and government, i.e., the cost incurred on education attainment or public expenditure on the education sector and R&D. The income-based approach (Mulligan & Sala-i-Martin, 1997) employs the income level of the individuals as a measure for the stock of human capital. However, the difference in earning might not truly reflect the difference in productivity of the individuals.

Human capital has been extensively studied in the literature with regard to its impact on macro and meso-level performance and productivity, economic growth and innovation. (McGuirk, Lenihan, & Hart, 2015) identified that human capital indicators such as education, training, job satisfaction, willingness to change have a positive impact on the product, process and service innovation in small firms and that these factors complement growth (job, sales, and productivity). These finding support the importance of innovative human capital for small-sized firms, in which

learning and willingness to change of the managers help with innovation generation. Similarly, the high intensity of human capital indicators like education, skills, creativity and experience are observed in green jobs, as compared to non-green jobs. Green jobs relate to the manufacturing and service industry which exhibits environmentally sustainable growth (Consoli, Marin, Marzucchi & Vona, 2016). The study infers that green jobs require a high level of cognitive and interpersonal skills and the measurement of human capital in green jobs entails a multi-dimensional approach in contrast to the approaches involving standard indicators like education, experience and training. In a cross-country data analysis, human capital has been found to positively influence the growth rate in total factor productivity (Benhabib & Spiegel, 1994). Finally, there is a prevalent consent on the critical role of human capital indicators related to education and skills on the economic growth rate (Mincer, 1981; Jameel & Naeem, 2016).

The literature on lessons learned from the implementation and fundamentals of smart cities considers human capital to be at the epicenter of smart city success. The Barcelona smart city initiative puts human capital as a pillar of foundation for smart city development (Bakici, Almirall & Wareham, 2013). The Barcelona smart city experience mandates the need for innovative and entrepreneurial human capital for a successful smart city implementation instead of simply considering the role

of public administration as a key ingredient for success. The collaboration platform for citizen engagement to trigger the community led innovations provided by the living lab model is being practiced in many smart city projects. Thus, one of the key areas of planning and development of a smart city is creating and containing the human capital in the city by improving educational standards, creativity, research culture as well as flexible work policies and incentives for the work force (Barrionuevo, Berrone & Ricart, 2012). Berry and Glaeser (2005) show the relationship between human capital and urban growth, where the skilled and qualified workforce having entrepreneurial capabilities brings innovation to the products, processes and services in different industries. Thus, the creative and educated class plays a critical role in the urban performance and urban wealth generation (Caragliu et al., 2011). While significant literature exists about the role of human capital in urban growth, innovation and productivity, the examination of human capital elements' criticality towards smart city success has not been comprehensively undertaken. The analysis of the role of human capital towards smart city development success necessitates the consideration of a multi-dimensional scope of human capital attributes in contrast to the previous studies.

2.2.3.2 Structural Capital

Structural capital comprises processes (organizational capital), physical and logical infrastructure such as communication systems, databases, software programs (technological capital) and the relationships amongst the different stakeholders (relational capital) (Lin & Edvinsson, 2010; Dameri et al., 2014). In the context of smart city development, the optimal arrangement of these components is for strong structural capital acting as the main pillar for city competitiveness and sustainability (Matos, Vairinhos, Dameri, & Durst, 2017). Uziene (2013) emphasizes the role of structural capital for the exchange of knowledge, information, goods and services between the different interest groups through the enabling of a supporting environment between community and institutions. The refinement of processes and the use of technology can improve the efficiency of public service delivery, eventually increasing the citizens' satisfaction. Singh, Tan, and Mookerjee (2011) investigated the role of internal cohesion, i.e., the interaction between the developers and the corresponding knowledge spill over, in open source projects success determined by the rate of knowledge creation measured through the modification requests in software or functionality addition. They found that the specific structure of the project's relationships affects the success of the project, justifying the importance of orchestration of structural attributes. Structural capital has also been found to have a positive and significant influence on business performance,

irrespective of the industry type (Bontis, Chua Chong Keow & Richardson, 2000).

In order to identify the structural components for smart city implementation, case studies on 24 smart city initiatives were examined. The service spectrum in these cities closely matches the smart city definition used in this research. These implementations are using ICTs to improve and refine service efficiency in an attempt to improve the quality of life for the citizens. While the service spectrum across these initiatives overlaps, there are different structural arrangements towards the development and management approaches, interaction of the stakeholders and the physical and logical infrastructure development and exploitation. For example, Anyang used a top-down development approach for the smart city with a centralized control architecture having a single control center, while Tel Aviv used a bottom-up approach, giving autonomy to the agencies involved in the smart city projects. However, it was realized that the use of the bottom-up approach resulted in difficulties with the integration of services and data. Similarly, the role of citizens in smart city development has been seen differently by different projects. Some cities find it beneficial to involve citizens in the policy and development process for smart city services, whereas other relied only on post-development feedback from citizens to improve the services. Table 2.3 lists the smart cities examined in this research along with the structural properties of the smart city projects.

Table 2.3 List of selected smart cities

Code	City	Structural Properties	Source
1	Orlando	Centralized control center, Data sharing protocol, Top-down approach, Feedback system for citizens, Vertical communication	(Lee et al., 2016b)
2	Singapore	Decentralized approach, Distributed databases across agencies (plan to develop integrated data), data sharing platform amongst agencies, Horizontal communication	(Lee et al, 2016a)
3	Anyang	Centralized architecture, Feedback system for citizens, Top-down approach, Central data in integrated control center with data/information sharing with relevant organization	(Lee et al, 2016c)
4	Rio-de-Janeiro	Centralized Control Centre, Open data, Top-down approach, Citizen participation in public policy and city development, Vertical Communication	(Schreiner, 2016)
5	Dubai	Public Wi-Fi, centralized, Top-down approach, Open data	(Smart Dubai 2021, n.d.) (Smart Dubai, n.d.)
6	Songdo	Top-down approach, Public Private Partnership, Mobile governance and information to citizens, Centralized control, Central data storage with information provisioning to public offices, portals and private businesses	(Kwon et al., 2016)
7	Tel Aviv	Bottom-up approach, Pre-project citizen engagement and post development feedback, Decentralized approach with shared ownership, Public private partnership using startup ecosystem, Data and information sharing	(Toch & Feder, 2016)
8	Santander	Single data and information storage, city council determines access profiles and potential uses. Data open to public, Public private partnership, Post development feedback, Decentralized control	(Gutiérrez, 2016)
9	Medellin	Decentralized approach, Citizen engagement in decisions Top down approach, Horizontal communication	(Amar, 2016)
10	Amsterdam	Open data (City data portal), Bottom up approach, Citizen engagement in smart city development, Decentralized	(Amsterdam smart city, n.d.)
11	London	Open Data, Decentralized, bottom-up approach (startup accelerators), Citizens engagement in policy making and decision/innovation	(Smart London Board, 2013) (Arup, 2016)
12	Pangyo	Centralized architecture, Feedback system for citizens, Top-down approach, Central data in integrated control center with data/information sharing with stakeholders	(Lee, Kwon, Cho, Kim, & Lee, 2016d)
13	Stockholm	Open Data, Public private partnership, Citizen engagement in decisions	(Buscher & Doody, 2013)

14	Seoul	Open Data, Public private partnership, Citizen engagement in development, Decentralized architecture, Public Wi-Fi	(Hwang & Choe, 2013)
15	Dallas	Public Private Partnership (Dallas innovation alliance) Open data, Top-down approach, Public Wi-Fi	(City of Dallas, 2018)
16	Vienna	Open data, Public Wi-Fi, Decentralized control, bottom up approach, Co-creation, citizen engagement/PPP	(Wien, 2014) (Smart city Wien, n.d.)
17	Berlin	Open data, Decentralized, bottom-up approach (startup accelerators, private companies) , Citizens engagement in innovation	(Smart city strategy Berlin, 2015)
18	Melbourne	Public Wi-Fi, Open data platform, City Lab for citizen engagement in community problem solving, Decentralized	(Melbourne as a smart city, n.d.) (Arup, 2010)
19	Oslo	Co-creation model, bottom up approach using startups, decentralized	(Smart Oslo, n.d.)
20	Moscow	Wi-Fi access on public places and public transport.	(How does a smart city work in Moscow, n.d.)
21	Islamabad	Public Wi-Fi, Centralized control, Top-down approach, Post development feedback	(Capital Development Authority, n.d.) (NADRA, n.d.)
22	Lahore	Public Wi-Fi, Centralized control, Top-down approach, Post development feedback	(PSCA, n.d.) (Punjab police, n.d.) (PITB, n.d.)
23	Shanghai	Open data	(Arup, 2014)
24	Beijing	Public Wi-Fi, Open data	(Liu & Peng, 2014)

The service spectrum of these case studies was categorized into mobility, citizen safety, disaster management, energy, environment, governance and economy (Schreiner, 2016; Lee et al., 2016a; Kwon et al, 2016; Toch & Feder, 2016) as summarized in Table 2.4. The numerical code for each city from Table 2.3 that has implemented the respective service in some form has been mentioned under the column smart cities.

Table 2.4 Service spectrum of selected smart cities

Service Spectrum		Smart Cities
Smart Mobility	1) Traffic information 2) Intelligent transport systems 3) Smart parking, 4) Electric vehicle use 5) Vehicle-to-grid, 6) Fleet management	[1-24]
Safety	1) CCTV + app based monitoring for crime prevention, 2) Fire unit, 3) Incident reporting system.	[1,3,6-9, 12, 14-15, 17, 20-24]
Disaster Management	1) Inter-agency coordination system, 2) Disaster alert system, 3) GIS usage for rescue and damage assessment	[1-5, 7-8, 12, 19-23]
Energy	1) Smart metering, 2) Energy consumption real-time info, 3) Solar energy (virtual power plant), 4) LED use and demand logic (sensor-based intensity control)	[1-2, 4, 6-17,19,21,24]
Environment	1) Measurement of air/water quality, 2) Weather information reporting. 3) Smart waste management & recycling, 4) Noise measurement and control	[1-9, 11-18,19-20,23-24]
Citizens/ governance	1) Open governance model, 2) Living Labs for inclusion of citizens, 3) Young startups into problem solving and policy	[1,3, 5-18,19-22,24]
Economy	1) Circular Economy, reducing waste and increasing recycling, waste food to soil conditioner, 2) Regulations for economy boost, 3) R&D and incubation centers	[7, 10,23]

It was observed that services implemented under the smart city umbrella across these cities highly overlap, with similar problems being solved, however, different approaches to development and management have been used. Furthermore, the context of these projects was also similar, with the focus placed on solving issues being raised due to urbanization. Therefore, a study was needed to investigate which structural arrangements are best suited for smart city development that can work as a guideline for those initiating new smart city developments.

Chapter 3 Study on the Role of Human Capital for Smart City Success

Smart city development and understanding has its foundation in three important factors; human factor, technology factor and institution factors (Dameri, 2017). A lack of attention to any of these factors could lead to failure or less efficient smart city implementations. The technology factor is more inclined towards the definition of the digital city where the use of technology products enables the digitization of the systems and fetching data from the city infrastructure. However, it is not enough to be designated as a smart city, unless the technology is utilized to make the processes efficient and increase the quality of life of the citizens. The institutional factor also plays an important role as the administrative structure, processes of the organizations, and the inter-organization harmony are critical to the smart city development (Yigitcanlar & Velibeyoglu, 2008). The communication and collaboration among the organizations ensures the development of a fully integrated smart city. The interconnection of the different systems like mobility management and the emergency response and the coordination amongst different government agencies for the public service delivery is necessary for the efficient and convenient provisioning of these services to the citizens. Finally, the human factor is the driving force for the smartness of city where the creative human capital can turn

raw data into useful information, build new solutions over existing information and devise and implement the suitable action plans. Therefore, the capabilities of human capital to learn and innovate are positioned at the center of smart city development.

The desired characteristics for human capital are spread across multiple dimensions that include the individual competences and expertise, as well as the collective intelligence and trend of the society. The innovative capability of human capital is complemented by the education level and training (McGuirk, 2015). Similarly, the behavioral characteristics of the workforce also influence the organizational learning and innovation (West, 2005; Montes, 2005). The conceptual idea of smart city by Nam and Pardo (2011) considers lifelong learning, creativity and ethnic plurality as important characteristics that enable human capital to contribute effectively to smart city development. The individual level attributes like education, experience and creativity have been investigated as the source of productivity and innovation at the firm and regional level. Similarly, lifelong learning (Attwell, 2007), ethnic plurality (Boubtane & Dumont & Rault, 2015) have been found to have growth effects by keeping employability and increasing productivity. The epicenter of a learning society is the R&D activity driving innovation (Martinez, Zouaghi, & Garcia, 2017) which eventually leads to the monetization of new ideas (Zygiaris, 2013) in the form of products, services and processes that are

vital to the smart city. The development of smart cities thus requires the parallel upgrading of the human capital factors along with technological development and institutional harmony.

3.1 Model

The model has been developed by identifying the human capital attributes using the existing literature by incorporating a multi-dimensional approach. The investigation of the role of human capital through the ranking of human capital determinants in the complex nature of smart city systems and the hyper connectivity amongst different function require thinking of human capital in a comprehensive scope. The human capital components have been divided into four categories that include personal qualifications, personal trait, culture and social factors. These categories cover individual level competencies as well as the collective capabilities and trend in the community. The components of human capital have been identified based on previous work related to their role towards efficiency, productivity, innovation and sustainable growth as discussed in the next sections. The hierarchical representation of human capital components is depicted in Figure 3.1.

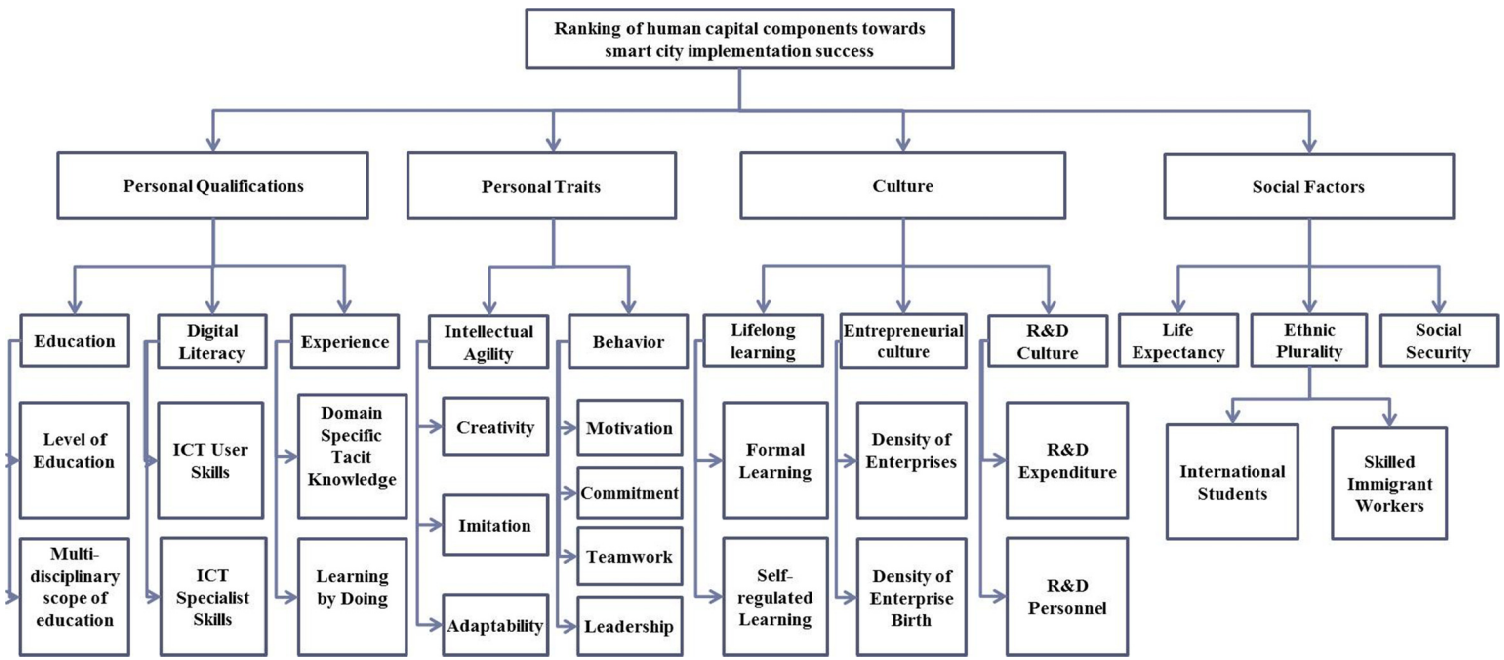

Figure 3.1 Hierarchical representation of human capital attributes

3.1.1 Personal Qualifications

The components of human capital categorized under the personal qualifications category are education, digital literacy and experience. Education is the most widely used component of human capital in analytical studies involving the role of human capital. The level of education attainment has been long considered as a gauge of productivity (Shapiro, 2006), innovative (McGuirk et al., 2015) and growth enhancing (Asteriou & Agiomirgianakis, 2001; Barro, 2001; Ortiz, Sosa, & Diaz, 2015) capabilities of the workforce, however, recently there has been a greater focus towards the multi-disciplinary scope of education, which nurtures critical thinking and problem solving abilities (Manju et al., 2017) of the individuals to tackle cross-sectoral problems (Jacob, 2015) and is thus matching the needs of industry (Bouras, Zainal, & Abdulwahad, 2016). The smart city being a system of systems requires individuals to critically analyze problems spanning multiple disciplines and devise efficient solutions, thus requiring knowledge of more than one area.

Second, ICT lies at the center of the smart city development which mandates digital literacy as an important component of human capital (Hargitti & Hinnant, 2008) to be considered as a success factor. ICT user skills are critical to the adoption of ICT enabled systems (Mac Callum & Jeffrey, 2014), which requires individual to possess sufficient knowledge to

operate devices, information systems and fetch useful information from the web. On the other hand, having specialist skills fuels community-led innovation and enables individuals to develop new programs for solving community issues and use the available data for smart decision making and process optimization (Hagsten & Sabadash, 2017).

The obtained years of experience of the individuals help accumulate tacit knowledge ready to be leveraged, which improves the efficiency through processes refinement and increases productivity (Hitt, Bierman, Shimizu, & Kochhar, 2001). Domain specific tacit knowledge is acquired by the individuals over the years through relevant industry experience. In case of non-existence of tacit knowledge, the learning by doing concept is practiced that follows the trial, failure, and success loop in the experiential learning process in order to upgrade the capabilities (Rui, Cuervo-Cazurra, & Un, 2016; Van, Streumer, & Stooker, 2001). While learning by doing is feasible in small-scale developments where the risks attached to failures are not significant, the integration of complex systems may result in poor outcome which supports the utilization of existing tacit knowledge. Table 3.1 summarizes the literature used in development of model for human capital.

Table 3.1 Selected literature for identifying the components of human capital

Categories	Components	Reference
Personal Qualification	Education	(Asteriou & Agiomirgianakis, 2001; Barro, 2001; McGuirk et al., 2015; Shapiro, 2006; Consoli et al., 2016; Ortiz et al., 2015; Manju et al., 2017; Jacob,2015; Bouras et al., 2016)
	Digital Literacy	(Hargitti & Hinnant, 2008; Mac Callum & Jeffrey, 2014; Hagsten & Sabadash, 2017)
	Experience	(Hitt, 2001; Rui, 2016 ; Van et al., 2001)
Personal Traits	Intellectual Agility	(Tovstiga & Tulugurova, 2009; Lee, Florida, & Gates, 2010; Cullen, Edwards, Casper & Gue, 2014)
	Behavior	(West & Hirst, 2005; Montes, Moreno, & Morales, 2005)
Culture	Lifelong Learning	(Knipprath & De Rick, 2015; Asplund, 2013; Steffens, 2015; Attwell, 2007)
	R&D Culture	(Guellec & Potterie, 2000; Wakelin, 2001)
	Entrepreneurial Culture	(Acs, Estrin, Mickiewicz & Szerb, 2018)
Social Factors	Ethnic Plurality	(Boubtane et al., 2015)
	Life Expectancy	(Acemoglu & Johnson, 2007; Sachs & Warner, 1997)
	Social Security	(Becker, 1994; Kemnitz & Wigger, 2000)

3.1.2 Personal Traits

Personal traits of human capital contain intellectual agility and behavior. Intellectual agility is the collective product of the personal attributes like creativity, imitation and adaptability (Tovstiga & Tulugurova, 2009). The solution for urban problems through innovative ideas using out-of-the-box thinking entails creativity as a critical attribute while imitation capability helps replicating existing solutions and processes available or implemented elsewhere in order to increase efficiency and productivity (Lee et al., 2010). The rapidly changing technological environment necessitates the adaptability of workers to a different environment, team, and job task without compromising their productivity and motivation (Cullen et al., 2014). The behavioral characteristics play a critical role in the output and productivity of the individuals and the organizations. Development of shared objective in teamwork helps the creation and precise filtering of new ideas which facilitate innovation (West & Hirst, 2005). Similarly, leadership support and the teamwork cohesion significantly influence organizational learning (Montes et al., 2005), which in turn promotes technical and administrative innovation. The convergence of processes and interconnections of subsystems in a smart city demands attention towards the workforce's behavioral characteristics like team cohesion, motivation, and commitment.

3.1.3 Culture

The components identified in the cultural category are lifelong learning, entrepreneurial culture and R&D culture. Lifelong learning comprises formal learning and self-regulated learning and indicates the tendencies of the workforce for continual learning and upgrading of skills in order to increase productivity or keep employability. Lifelong learning is a mandatory requirement for the effectiveness of human capital in a changing business environment, where production processes and technologies demand a continuous upgrade of the skill set (Asplund, 2013). Formal learning is the process of improving the skills and capabilities of individuals through onsite or offsite formal training by the organizations (Knipprath & De Rick, 2015). Self-regulated learning (Steffens, 2015) is the self-motivated improvement of skills by individuals through available resources in print and electronic format including organized resources like MOOCS or scattered resources like short lectures in order to increase occupational competencies (Attwell, 2007). Entrepreneurial culture significantly influences economic growth (Acs et al., 2018) and has been represented as the density of enterprises and the density of enterprise births to cater for the death rate of the newly established enterprises. It is important because new startups are characterized by a flexible work environment which supports innovative activities and, despite the possible

failure of the startup, can contribute with useful knowledge. The attribute depicts the tendency of the workforce to develop ideas into products or services and commercialize them. The smart city model involving the private sector can benefit from this entrepreneurial culture to outsource specific product or service-related tasks to young startups. R&D culture triggers innovation (Guellec & Potterie, 2000) in the city and is captured in the model through the variables R&D expenditure and number of R&D personnel. R&D expenditure improves the firm-level productivity as previously studied by Wakelin (2001).

3.1.4 Social Factors

Human capital studies focus on the development of human capabilities as well as the accumulation of creative and innovative human capital. The consideration of social factors is based on their ability to attract the creative class to the urban area under consideration. The considered social factors include the life expectancy of the population at birth, social security and ethnic plurality. Life expectancy as a measure of human capital has been employed by Sachs and Warner (1997) who found an effect of high life expectancy (i.e. 70~74) on economic growth, above which the effect on growth was negligible. However, Acemoglu and Johnson (2007) advocate that the growth effects of life expectancy are very small. Ethnic plurality has been considered to play an important role in innovation and growth

where innovative minds together create more opportunities and the knowledge spillover effect benefits the overall economy. The creative class tends to form clusters in urban areas which results in the ethnic diversity of the region, which can be used as an indicator of the potential for innovation. The number of international students studying in the academic institutions and the skilled immigrant workers in the industry measures the ethnic plurality of the region which plays a positive role in the economic growth of the region (Boubtane et al., 2015). Different forms of the social security systems ensure the welfare of the public, which is beneficial for human capital accumulation. Loans for the education of students to be repaid from parents' old age benefits will help create a more educated workforce, which in turn drives the growth engine (Becker, 1994). According to Kemnitz and Wigger (2000), a properly deigned social security system complements the economic growth only when human capital instead of physical capital is the engine of growth.

3.2 Methodology

Analytic Hierarchy Process (AHP) is the methodology used for ranking the critical components of the human capital for smart city implementation success. AHP is a multi-criteria decision making technique (Saaty, 1987; Saaty, 1990) for the selection of alternatives having multiple attributes, which can also be used for prioritization and ranking of attributes with

respect to their importance towards a goal. The choice of AHP was driven by the following factors: 1) it is a well-proven technique applied in a broad set of applications which validates inconsistency in multi-criteria collaborative decision making, 2) it can be applied to unstructured problems having tangible and intangible factors where problems are structured into a hierarchy, and 3) the use of a ratio scale. The hierarchical structure breaks the complex problem into small understandable elements, thus reducing the complexity of the decision problem. The ratio scale, in contrast to an interval scale, provides a relative value where an attribute is compared in terms of the compared attribute, allowing the comparison of items with different units, which is needed in this study. AHP comprises five steps which are: problem modeling, judgment scale questionnaire, pair-wise comparison, priorities derivation and consistency check (Saaty, 2008).

First, the components and subcomponents of human capital have been organized in the hierarchical structure shown in Figure 3.1, thus categorizing the factors into clusters which prevent these factors from differing in extreme ways during pairwise comparison. The goal of ranking these elements per their importance towards smart city implementation is at the top of the hierarchy.

The pairwise comparison questionnaire was designed for the human capital elements in order to fetch responses from experts. This questionnaire used the numerical judgment scale 1-9, the verbal equivalence of which can be seen in the questionnaire in Appendix B.

The comparison matrix that records the judgments of the respondents should be consistent, thus satisfying the transitivity rule. However, in real world scenario, there is a chance of inconsistency to be found in the comparisons.

The priority weights of the human capital attributes were estimated using the equation $A.P = \lambda_{max}.\mathrm{P}$ while solving for the principle eigenvector 'P'. Here A is the n x n comparison or priority matrix for n number of factors, P is the eigenvector of size n x 1, and λ_{max} is the maximum eigenvalue.

Finally, the consistency of the assessment is calculated to check for its acceptability. The consistency ratio (CR) must be less than 10% for the results to be accepted and is calculated as CR= CI/ RI. Here, CI is the consistency index, which is calculated as $(\lambda_{max} - \mathrm{n})/(\mathrm{n} - 1)$ where n is the dimension of the comparison matrix, and λ_{max} is the maximum eigenvalue. A perfectly consistent matrix will have a CR equal to zero; however, it is hard to achieve this value due to differences in the judgment

performed by different people. Therefore, a slight inconsistency in the comparison matrix can be accommodated in the estimation process.

RI is the random index, which is the average of the 500 randomly filled matrices. RI values as calculated by Saaty (1994) are given in Table 3.2.

Table 3.2 Random Index (RI) values

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

3.2.1 Survey for Analytic Hierarchy Process

The survey for the role of human capital in smart cities using the AHP questionnaire for identifying the preferences of experts was conducted online and prepared using the freely-available open source software Lime survey[1]. The decision for conducting online survey was influenced by the fact that the targeted experts were at different geographical locations across multiple countries. The survey contained pairwise questions comparing the different elements of human capital using a 9-point ratio scale and questions on the demographic characteristics of the respondents like experience, country and affiliated organization. A sample question for comparison of human capital attributes for the priority weights estimation is given in Table 3.3.

[1] https://www.limesurvey.org/

Table 3.3 Sample survey question for AHP

What is the more important attribute of education that contributes to the success of smart city implementation?

Level of Education	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multi-disciplinary scope of education

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

AHP can be applied from one to as many judgments as there are participants, however in order to ensure the reliability of the results, the number of participants should be reasonable. Different researchers have used different number of participants, from as low as five (Peterson, Silsbee, & Schmoldt, 1994) and seven participants (Armacost, Componation, Mullens & Swart, 1994). The number of participants also depends upon the size of the potential audience. The respondents for this study were selected from ICT experts working in the area of smart city in academia and industry including governments and the private sector. A total of 31 participants' judgments were used for the analysis out of the 36 responses received as five responses were excluded due to their high inconsistency. Participants were provided with the study objectives, a definition of the scope of smart city and descriptions of the variables used in the model in order for them to understand the exact meaning of these attributes before answering the questionnaire to record their judgments as

different definitions and understandings of of smart cities can lead to inconsistent results.

The number of respondents having more than 10 years of experience was 22, whereas 8 respondents' work experience was between 8 and 10 years. The country and organizational distribution of the respondents is given in Table 3.4 with one respondent being a self-employed consultant.

Table 3.4 Respondent's demographics

Country wise distribution of respondents			
Pakistan	19	Saudi Arabia	2
Belgium	1	Canada	1
Republic of Korea	2	Japan	2
Indonesia	2	United Kingdom	2
Organization wise distribution of respondents			
ITU	2	Lahore College for Women University	1
NADRA	3	Teradata	3
PITB	4	TEIN*CC	2
IBM	2	Quaid-e-Azam University	3
SZABIST	2	Tohoku University	2
NUST	2	Al Yamamah University	2
COMSATS	1	Leiedal	1

3.3 Estimation of Results

The category-wise priority weights and the overall priority weights of the human capital determinants with respect to their importance towards the smart city implementation success were calculated using expert choice software. The priority weights for Level 1 of the AHP tree are given in Table 3.5. The personal qualification importance priority towards smart city success is 0.378 (37.8%), whereas personal traits category has received 0.256 (25.6%) priority weights. Similarly, culture and social factors were found to have 0.296 (29.6%) and 0.070 (7%) priority weights, respectively. The consistency ratio is 0.00588, which is within the acceptable range of less than 0.1.

These components are ranked based on their received priority weights, where personal qualification of the human capital can be seen as the most dominating category having ranked first with 37.8% importance, followed by culture, having a relative importance of 29.6% staying at second place. Social factors received priority weight of 7% which is very low as compared to the other components depicting that experts do not prefer social factors as the critical elements of human capital for smart city development.

Table 3.5 Human capital components priorities

Components	Priority Weight	Rank
Personal Qualification	0.378	1
Personal Traits	0.256	3
Culture	0.296	2
Social Factors	0.070	4
CR= 0.00588		

The priority weights for the personal qualification category are presented in Table 3.6. In this category, experience has been ranked number 1, with an estimated priority weight of 0.446 (44.6%), followed by education with a priority weight of 0.306 (30.6%). Finally, digital literacy placed last with a 0.248 (24.8) priority weight.

Table 3.6 Personal qualifications attributes priorities

Components	Priority Weight	Rank
Education	0.306	2
Digital Literacy	0.248	3
Experience	0.446	1
CR=0.01		

As can be seen in Table 3.7, intellectual agility has been ranked higher under the personal trait category with a priority weight of 0.69 (69%) whereas behavior obtained 0.31 (31%) priority weight.

Table 3.7 Personal traits attributes priorities

Components	Priority Weight	Rank
Intellectual Agility	0.69	1
Behavior	0.31	2
CR=0.0		

Similarly, the culture category in Table 3.8 contains entrepreneurial culture as the highest ranked attribute with a priority weight of 0.445 (44.5%), with successor R&D culture acquiring a priority weight of 0.392 (39.2%). Lifelong learning was placed last with a priority weight of 0.162 (16.2%).

Table 3.8 Culture attributes priorities

Components	Priority Weight	Rank
Lifelong Learning	0.162	3
R&D Culture	0.392	2
Entrepreneurial Culture	0.445	1
CR=0.00013		

Finally, as shown in Table 3.9, social security is the top ranked attribute under the category of social factors, with a priority of 0.399 (39.9%). However, there is no significant difference of priority weight between social security and ethnic plurality. Therefore, these two factors are seen by experts having similar importance with respect to their parent node in AHP tree i.e. social factors.

Table 3.9 Social factors priorities

Components	Priority Weight	Rank
Life Expectancy	0.236	3
Ethnic Plurality	0.365	2
Social Security	0.399	1
CR=0.00152		

Table 3.10 shows the priority weights of the attributes at Level 3 of the hierarchy along with their corresponding ranks with respect to the parent node. The parent node is being mentioned in the shaded rows, e.g., education, digital literacy, and experience etc. Ranking of the attributes in the category wise estimation has a local scope and applies to the comparison with other nodes under the same parent.

Table 3.10 Level 3 attributes priorities

Attributes	Priority Weight	Rank	Attributes	Priority Weight	Rank
Education			Commitment	0.156	3
Level of Education	0.219	2	Teamwork	0.135	4
Multi-disciplinary scope of education	0.781	1	Leadership	0.473	1
Digital Literacy			**Lifelong Learning**		
ICT User Skills	0.433	2	Formal Learning	0.326	2
ICT Specialist Skills	0.567	1	Self-regulated Learning	0.674	1
Experience			**Entrepreneurial Culture**		
Domain specific tacit Knowledge	0.542	1	Density of Enterprises	0.376	2
Learning by doing	0.458	2	Density of Enterprises Birth	0.624	1
Intellectual Agility			**R&D Culture**		
Creativity	0.474	1	R&D Expenditure	0.236	2
Imitation	0.142	3	R&D Personnel	0.764	1
Adaptability	0.385	2	**Ethnic Plurality**		
Behavior			International Students	0.292	2
Motivation	0.236	2	Skilled Immigrants	0.708	1

The overall priority weights of the human capital determinants depicting their estimated relative importance towards smart city implementation have been presented in Figure 3.2. In the estimation scenario with geographically dispersed participants, the overall consistency ratio is considered more important than the individual participants' consistency (Basak & Saaty, 1993). The overall CR in this case was found to be 0.1, which falls within the acceptable range. It is obvious from the overall priority weights that the attributes from experience, education and R&D culture are cited as most important towards smart city success.

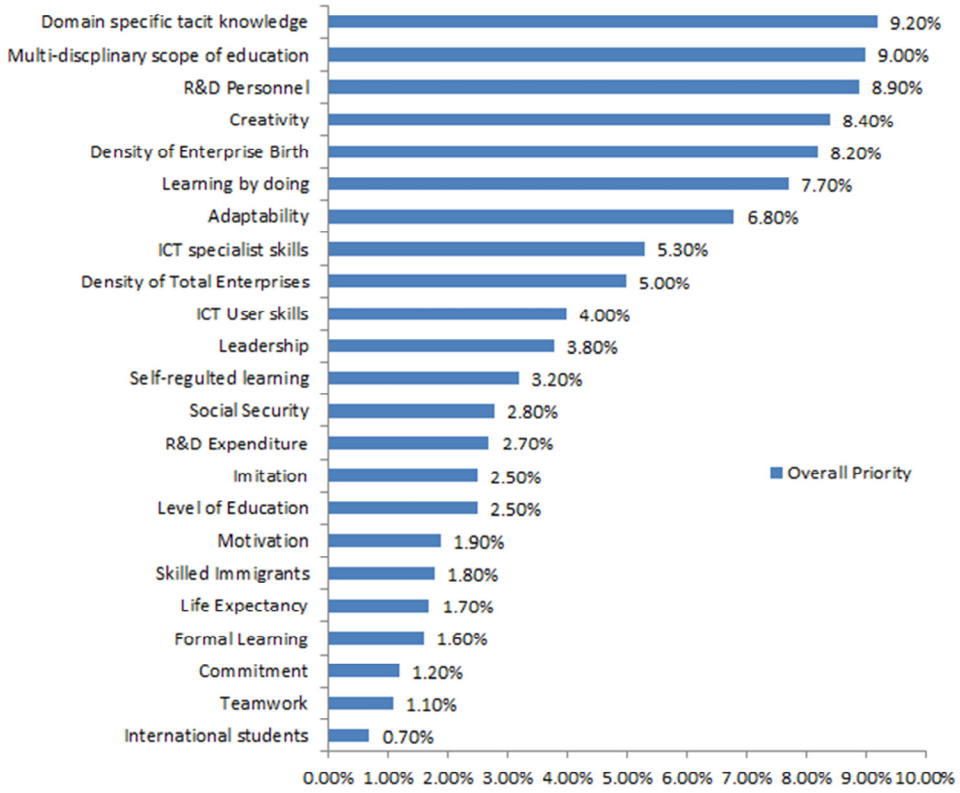

Figure 3.2 Overall priority weights of the human capital components

The comparison of judgments between the respondents from academia and industry for the human capital attributes is given in Figure 3.3. It is clear that a disagreement exists between the preferences of experts from academia and industry, which is very wide in case of the indicator of digital literacy. However, it is clear that the same trend is being followed for most of the attributes across the two groups of participants. It is a good indicator of the consistency of the results and supports the premise that an increase in the number of participants will not significantly impact the ranking of attributes.

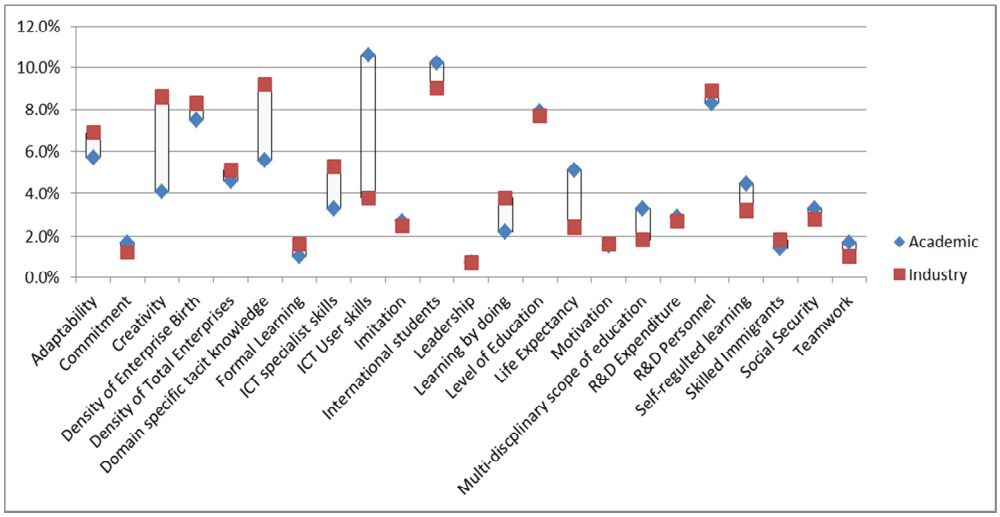

Figure 3.3 Comparison between academia and industry respondents

Figure 3.4 shows the comparison of priority for human capital attributes between the respondents from Pakistan and other countries. There were no significant variations observed between the priorities apart from the

attributes on ICT specialist skills and R&D expenditure. The respondents from Pakistan put a higher priority for the ICT specialist skills than other countries, while at the same time they considered R&D expenditure less preferred. However, the overall differences between the two groups for preferences towards human capital attributes are not huge, demonstrating the consistency of the results.

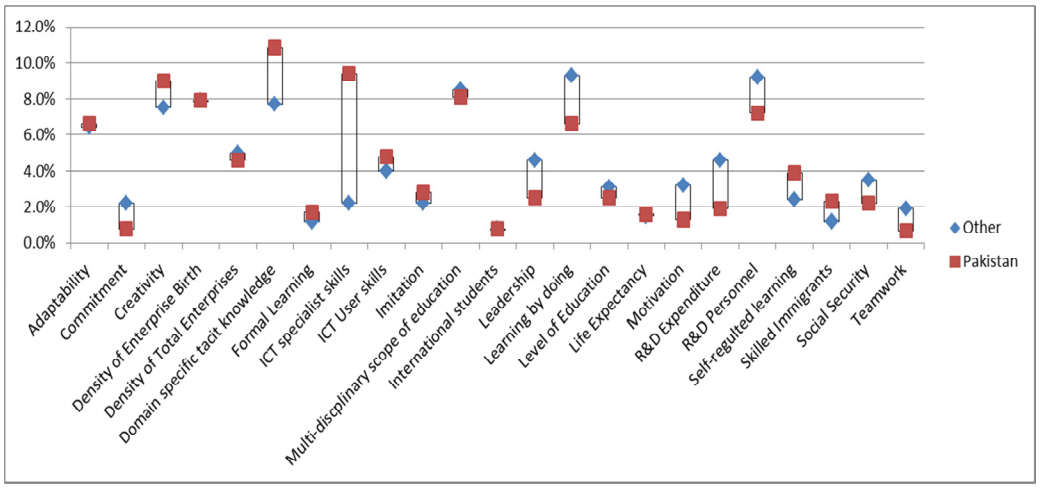

Figure 3.4 Comparison between respondents from Pakistan and other countries

Chapter 4 Study on Structural Capital Role for Smart City Success

Structural capital is the knowledge contained in the organization and does not leave with the employee. This knowledge or intangible value is hidden in the organizational procedures, databases and its relationship in the form of coordination, collaboration and contracts. The knowledge flow in the organization and the corresponding learning depends upon the specific organizational structure (Koohborfardhaghighi, Altmann, & Tserpes 2017). The fully hierarchical structure and all direct connections were found by Koohborfardhaghighi et al. (2017) as the non-feasible options. However, the organizational internal structure is more tightly coupled whereas the smart city information flow takes place amongst relatively loosely-coupled organizations. Similarly, the firm's prime objective is to utilize the value sources in structural capital in order to increase the financial performance; however, the smart city objective is to ensure the efficiency and sustainability of the urban functions. Structural capital in a smart city varies from firm-level studies due to scope, objective and the shared ownership among the participating organizations for resources like data. Furthermore, the studies focus on specific indicators of interest like group turnover or number of domestic offices (Ordonez de Pablos, 2004) that are strictly related to firm-level analysis. There is an availability of different

alternatives for structural capital attributes in smart city implementation choice, which can impact the efficiency of the developed end system.

The different structural arrangements in smart city implementation models are illustrated in Figure 4.1 and Figure 4.2 based on the smart city cases presented in Table 2.3.

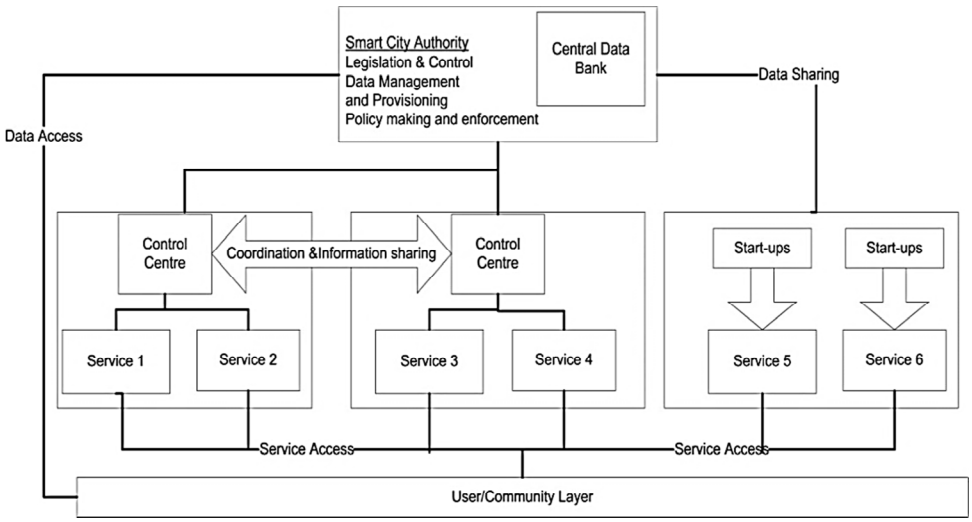

Figure 4.1 Structural arrangement of smart city - scenario 1

As depicted in Figure 4.1, the distributed implementation of smart cities, along with giving autonomy to the organizations would result in a decentralized system where the corresponding organization would be keeping the ownership of the services (Lee et al, 2016a). The use of the public private partnership mode will allow the private sector to participate in service provisioning, however the smart city authority can either keep the data centrally (Gutiérrez, 2016) or let the organizations assume

ownership. The role of the smart city authority in city operations varies with the choice of the structural orchestration.

Similarly, in a scenario where the central control is kept for the smart city services, the collaborating organizations have a central point of contact for information and coordination as shown in Figure 4.2. In this scenario, the services of the private sector are obtained at the infrastructure or skill-level, however the ownership and control of the services and data stays with the smart city authority (Kwon et al., 2016). Besides these scenarios, there are multiple options for choosing the structural capital attribute including the development approach, data management and information system development which are utilized in the development of a model for structural capital in the next section.

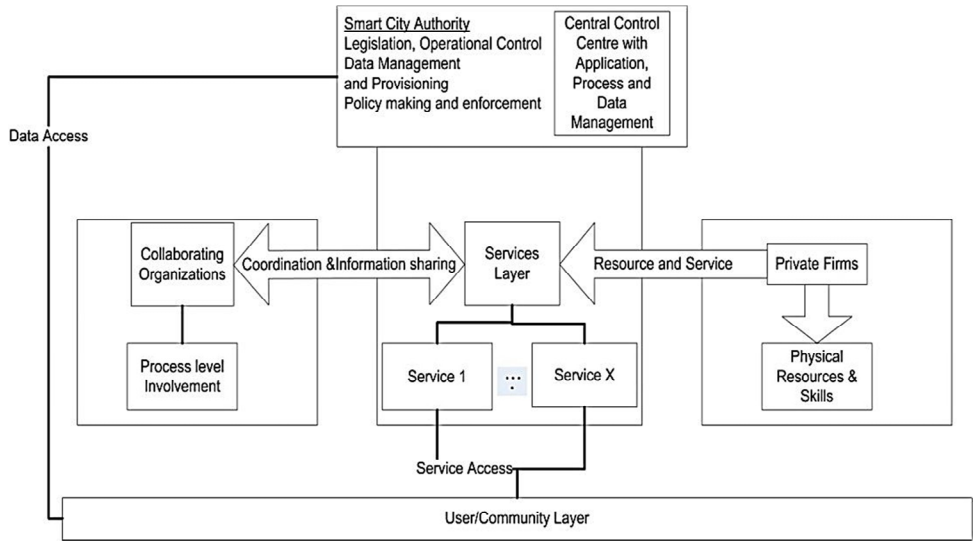

Figure 4.2 Structural arrangement of smart city - scenario 2

4.1 Model

The model for ranking the structural capital components towards the success of smart city implementations has been developed in hierarchical form as shown in Figure 4.3. The structural capital components are categorized into the process, relational and infrastructural dimensions following the definition of Lin and Edvinsson (2010) and Dameri et al. (2014). These components have been identified by examining the case studies of smart city implementations across the world and include the development approaches being used, i.e., top-down and bottom-up approach, and the control and management mechanism for smart city services which can be either centralized or decentralized. The relational part looks into the mode of interaction between the participating agencies in the smart city and the communication between agencies and the citizens. These components are further explained below. The use of these different alternatives as given in the leaves of the AHP tree in Figure 4.3 results in different development and performance outcomes.

4.1.1 Process Elements

The components covered under the process dimension are policy, development method, and management & control. Smart city development approaches that have been used are the top-down approach and the bottom-

up approach. The top-down approach starts with the overall planning of the smart city development considering the services in context of their scope, interactions, participating and potential collaborating organizations followed by the implementation and operation phase (Schreiner, 2016; Amar, 2016; Lee et al., 2016b). Korean cities Songdo (Kwon et al., 2016) and Anyang (Lee et al., 2016c) are key examples of using a top-down approach for the implementation of the smart city concept. On the other hand, the bottom-up approach starts with an integration of existing services and a continuous integration of new services as they are developed into a smart city platform. Examples are the cases of Tel Aviv (Toch & Feder, 2016), Vienna (Wien, 2014) and Berlin (Smart city strategy Berlin, 2015). There is a challenge of the choice of development method as the top-down approach can get the support of existing corporate solutions from enterprises such as Cisco and IBM. However; the bottom-up approach is a suitable approach for nurturing innovation in the local community (Hojer & Wangel, 2015).

Management and control of smart city services can be done either in centralized or decentralized modes. The centralized mode uses only one integrated smart city control center that manages all the services and bears responsibility for collecting the generated data, their storage, ownership and dissemination to the respective users. The centralized mode has been used by many cities for their smart city implementations (Schreiner, 2016;

Lee et al., 2016c; Lee et al., 2016d; Kwon et al., 2016). Berlin, Singapore (Lee et al., 2016a) and many other cities follow the decentralized mode of management and control for their smart city systems. All of the organizations work in autonomy and manage their own control center or smart city services in case of a decentralized mode of control and management (Arup, 2016; Amar, 2016). The collaboration and information/services sharing between organizations occurs whenever needed in direct communication.

The smart city success is complemented by the presence and implementation of policies that support the development process. The mandate for these policies can differ from national-level jurisdictions to the local level in the metropolitan area (Angelidou, 2014). While the delegation of powers for these policies could differ across democracies, in the context of this study, they have been classified into national-level policies like funding support (National League of Cities [NLC], 2016), taxation and the existence of privacy and cyber laws (Elmaghraby & Losavio, 2014) and local-level polices like innovation growth policies and public private partnership (Gutiérrez, 2016) for smart city projects enforced by the metropolitan government.

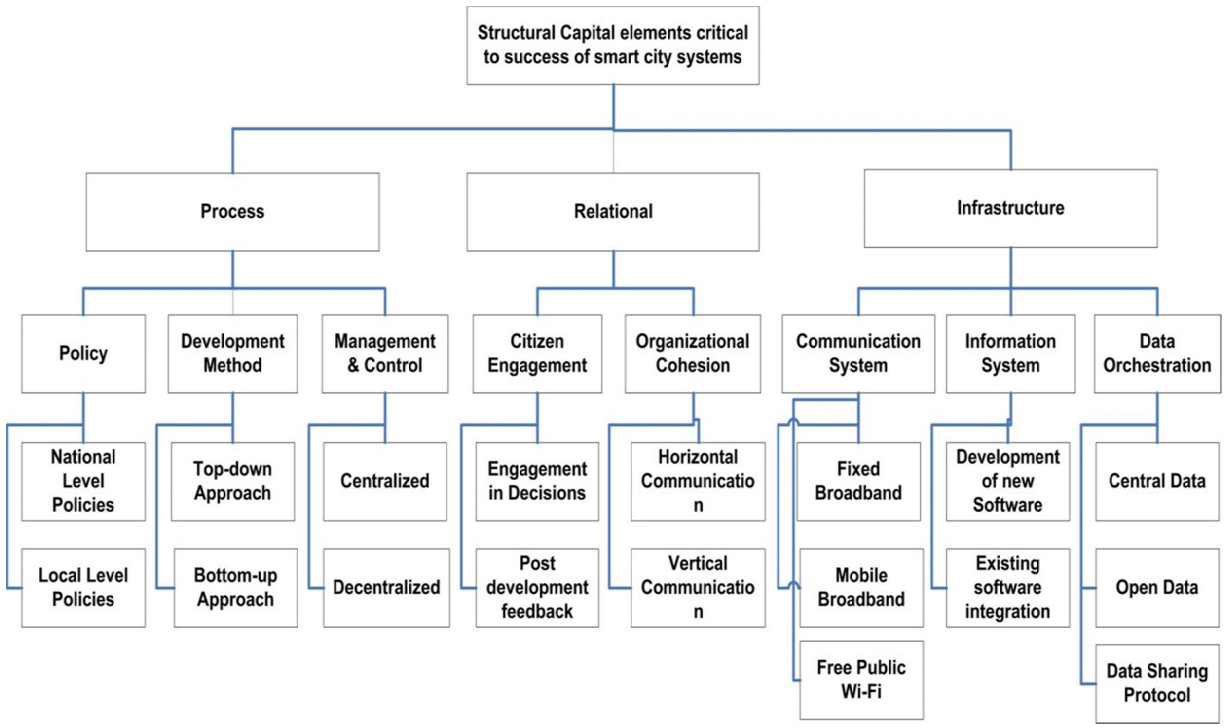

Figure 4.3 AHP tree for structural capital elements

4.1.2 Relational Elements

The relational dimension of structural capital in smart city development considers value sources generated from organization to organization and organization to citizen communication (Nam & Pardo, 2011a; Nam & Pardo, 2011b). The citizen engagement mechanism either involves citizens in the decision making processes of smart city development (Schreiner, 2016; Arup, 2016) or uses post-development feedback (Gutiérrez, 2016; Lee et al., 2016d) to refine and improve the effectiveness of smart city services. The citizen engagement in the decision making process for the development of new services, applications and projects targeted to address community issues helps in bridging the gap between the expectations of the users and the government's perception of the proposed solution. In the case of post-development feedback, only the users' feedback/complaints received through the smart city support center are considered in refining the services to better serve the citizens.

Organizational cohesion defines the mode of interaction between the participating organizations under the smart city umbrella. The horizontal communication mode involves direct communication between the peering organizations without the need of a central authority or integrated control center as in the case of Singapore (Lee et al., 2016a). While this mode provides more autonomy to the organizations along with a quick access to

required information/service, it puts burden on the organization when the number of peering organizations is high. Similarly, vertical communication for service request and information sharing occurs amongst the collaborating organizations through the smart city authority and is helpful in central management and record of transactions and simplicity of communication partner for the different agencies (Lee et al., 2016b; Schreiner, 2016).

4.1.3 Infrastructural Elements

The infrastructural dimension of structural capital comprises the communication systems, information systems and data orchestration (Edvinsson & Sullivan, 1996). While the penetration rate of fixed and mobile broadband indicates the number of connected citizens, which are potential users of the smart city services, there have been initiatives across different cities for provisioning free Wi-Fi in public places (Arup, 2010; Wien, 2014; Hwang & Choe, 2013) in order to increase the number of users through this incentive. The presence of high speed communication infrastructure is fundamental to the smart city development as it ensures the connectivity of the end users and the reliable and speedy transport of data. The choice of fixed or mobile broadband varies based on the type of devices and the quality and reliability of the communication network.

The integration of government agencies into the smart city umbrella requires the digitization of their processes through the implementation of information systems covering internal routines, external procedures for communication with peering organizations and end users. One way to achieve this is to use the existing information systems at the participating organizations (Toch & Feder, 2016) into the smart city operating system, with modifications, if needed. While this method reduces the development effort and contains benefit of utilizing users' existing operating skills, interoperability issues could undermine the system's performance and robustness (Chourabi et al., 2012). The development of new information systems and programs specifically designed to be used for smart city operating systems would result in a more efficient and interoperable system, even though the development costs are higher.

Finally, there have been different mechanisms used by smart cities implementation for the database management and its provisioning to the different stakeholders. In case of central data storage, all the data is stored at a central location and the smart city authority has the ownership and decision rights for data sharing (Gutiérrez, 2016). The benefit of central data storage is the single management of the data repository and its provisioning to the interested stakeholders which brings about efficiency and ease in the data management processes. Interested entities intending to fetch any type of smart city data will have to deal with only one single

entity/organization instead of dealing with several points of contact in case of distributed data. It can also help in ensuring that no inconsistencies, duplication and conflicting data types exist for the different attributes. The open data model, which is popular across cities (City of Dallas, 2018; Liu & Peng, 2014; Arup, 2014), shares the data gathered through smart city services openly with everyone including different organizations and citizens while considering the security and privacy concerns. The open data model allows citizens, startups and entrepreneurs to use this data, which supports the innovative development environment in the city. The data is made available to the interested individuals and organizations free of charge in the case of the open data model. In the distributed storage architecture for data in cases like Singapore (Lee et al., 2016a) and Orlando (Lee et al., 2016b), the data and information sharing amongst the peering organization and the smart city authority requires the enforcement of a data sharing protocol defining the policies, access rights and sharing mechanisms. Due to the autonomy of the organizations and agencies working on smart city projects, they have to coordinate with the peering organizations and devise a policy for data sharing which could be required in the processes of the interested organization. In this scenario, any change in the source has to be communicated to all the dependent organizations, which, if not done correctly, might cause disruptions in the processes of these organizations.

4.2 Methodology

This methodology used in this study on structural capital role in smart city implementations is also the Analytic Hierarchy Process (AHP), for which the details have already been provided in Section 3.2 of this dissertation. Therefore, these details are not reproduced here.

4.2.1 Survey for Analytic Hierarchy Process

The survey questionnaire for structural capital role in smart cities contained pairwise comparison questions using a 9-point scale, an example of which is given in Table 4.1. The survey was conducted jointly for the sections on the role of human capital as well as structural capital in smart cities due to the same respondents.

Table 4.1 Sample question for AHP questionnaire for structural capital

What is the more important Relational component of structural capital that contributes to the success of smart city implementation?

Citizen Engagement	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Organizational Cohesion

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

The description of the attributes used in the pairwise questionnaire for structural capital role in smart city was provided to the respondents so that the corresponding results are consistent across different respondents,

instead of reflecting variations due to different understanding. The participants in this group decision making were also informed about the scope and definition of the smart city considered in this research due to the existence of difference definitions of smart cities across literature.

The demographic information of the respondents, who participated in this survey, is given in Figure 4.4. This information contains the country of workplace, name of the organization, and the number of respondents who participated in the survey from the respective organization.

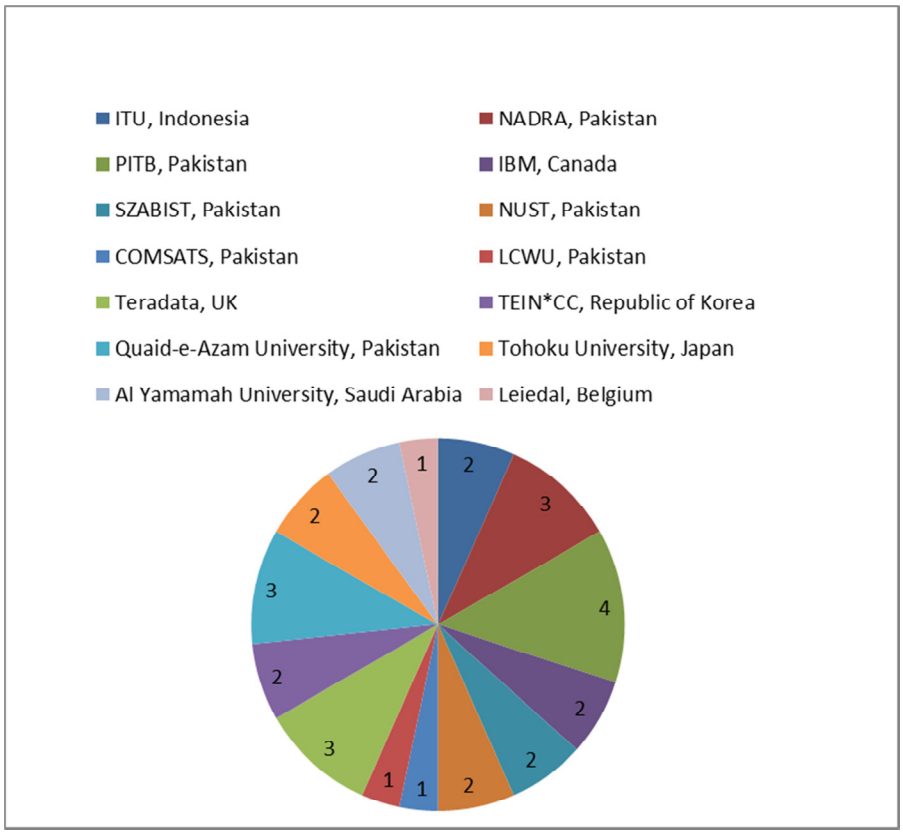

Figure 4.4 Demographics of the respondents

4.3 Estimation of Results

Expert choice software was used to calculate the priority weights of the structural capital elements to identify the critical elements towards smart city success based on the survey responses acquired from the experts. The local (category wise) and the global (overall) priorities are calculated for the nodes of the AHP tree. It is important to analyze the results considering the specific model. In case of an AHP tree, which is not balanced, the nodes with a smaller number of siblings may acquire a higher overall priority. Therefore, category-wise priority weights must be considered while discussing the impact of results on the policy directives.

Table 4.2 gives the local priority weights of the structural capital element's categories (Level 1 of the AHP tree) where process category priority weight was estimated to be 0.330 (33%), relational category acquired 0.127 (12.7%) weights and the infrastructure dominated by getting 0.543 (54.3)% priority weight. The consistency ratio was calculated as 0.02, which is within the acceptable range. At this level, infrastructure is the most dominant category for smart city success as per the experts' opinion. The process category was placed at rank 2, with relational being the least important category.

Table 4.2 Structural capital components priorities

Components	Priority Weight	Rank
Process	0.330	2
Relational	0.127	3
Infrastructure	0.543	1
CR= 0.02		

Under the process category, the priority weights of the components; policy, development method, and management and control are estimated to be 0.633 (63.3%), 0.114 (11.4%) and 0.253 (25.3%) as given in Table 4.3. Policy has been ranked as number 1, being the most important component in this category.

Table 4.3 Process attributes priorities

Components	Priority Weight	Rank
Policy	0.633	1
Development Method	0.114	3
Management & Control	0.253	2
CR=0.05		

As seen in Table 4.4, citizen engagement is the dominant component of the relational category with a priority weight of 0.602 (60.2%) followed by organizational cohesion acquiring a priority weight of 0.398 (39.8%). Finally, Table 4.5 gives the priority weights under the structural capital's category of infrastructure. The most important component was found to be the information system with a priority weight of 0.384 (38.4%) whereas communication system was considered as the second most important component under the infrastructure category having a priority weight of 0.375 (37.5%). The difference of priority between these two components is very low, depicting the criticality of both communication and information systems for smart city success. Data orchestration was placed at number 3, with a priority weight of 0.240 (24%). The consistency ratios (CR) estimated for all categories are given in their respective tables.

Table 4.4 Relational attributes priorities

Components	**Priority Weight**	**Rank**
Citizen Engagement	0.602	1
Organizational Cohesion	0.398	2
CR=0.0		

Table 4.5 Infrastructure attributes priorities

Components	Priority Weight	Rank
Communication System	0.375	2
Information System	0.384	1
Data Orchestration	0.240	3
CR=0.00018		

Table 4.6 presents the priority weights and rank (with respect to the parent node) of the Level 3 attributes of the AHP tree. The parent nodes are given in the shaded rows. Local level policies, top-down development method and the centralized management and control under the process category are considered relatively more important for smart cities implementations. In the relational dimension, respondents have given more importance to the citizen engagement in the development decision and the vertical communication between the agencies under the smart city umbrella. There is a huge difference in priority weights of the citizen engagement in decision making and the use of post development feedback, which depicts the strong inclination of respondents towards the involvement of citizens in smart city development. Finally, in the infrastructure category, open data, development of new information system and the provisioning of public Wi-Fi are considered critical by the experts towards smart city success.

Table 4.6 Level 3 attributes priorities

Attributes	Priority Weight	Rank	Attributes	Priority Weight	Rank
Policy			**Organizational Cohesion**		
National Level Policies	0.393	2	Horizontal Communication	0.402	2
Local Level Polices	0.607	1	Vertical Communication	0.598	1
Development Method					

The variation in preferences for structural capital attributes between academia and industry experts is presented the Figure 4.6. The preferences between academia and industry experts vary across different parameters. They are more consistent for the attributes of communication and information system, while the difference is more pronounced for the development approach.

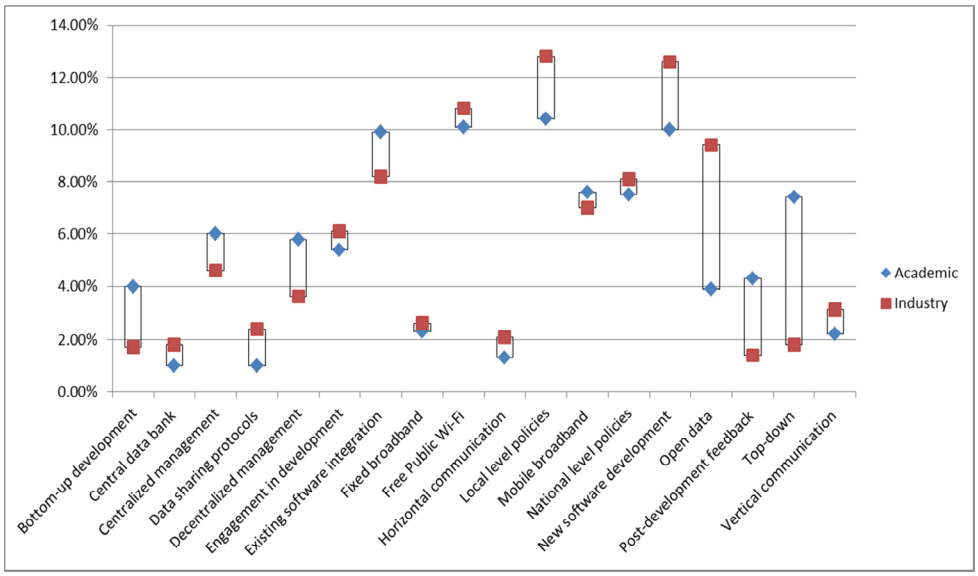

Figure 4.6 Comparison of academia and industry respondents

The comparison between the respondents from Pakistan and other countries is given in Figure 4.7. The choices between these groups are consistent across most of the attributes, having only very slight differences apart from the element public Wi-Fi under the infrastructure part, where the disagreement is much higher. Provisioning of public Wi-Fi is highly

preferred by the respondents from Pakistan. Overall, the comparison between academia and industry and respondents from Pakistan and other countries depicts that the results are consistent across most of the attributes and increasing the number of respondents will not make any significant difference. The difference of preference towards free public Wi-Fi can be related to the huge difference in the income level between Pakistan and the other countries considered in this study.

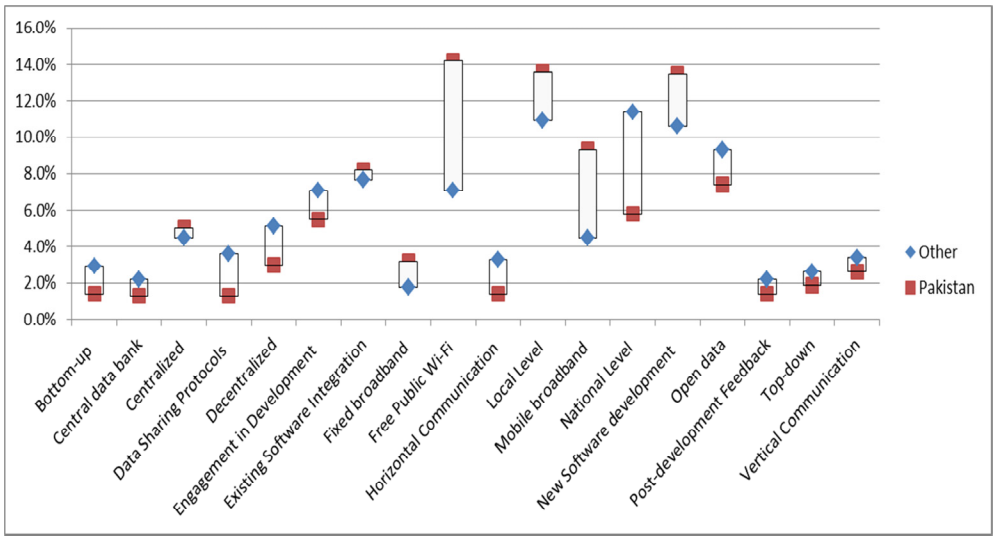

Figure 4.7 Comparison between respondents from Pakistan and other countries

Chapter 5 Adoption of Smart City Information Services

5.1 Citizen's Preferences Analysis towards the Adoption of Smart City Information Services

Smart city implementations extend services to the citizens as information services, which could be isolated across different agencies or bundled with multiple functionalities. The adoption of these services by the citizens is an important aspect to be considered for the success of smart city implementations. The data generated in the smart city is a highly important instrument for the further refinement of the different systems and procedures. Therefore, the collection of data for citizen-centric services depends upon the number of users, requiring a widespread adoption of the information services. Thus, an increasing number of users ensure the higher value of the service for the users (Haile & Altmann, 2016). A safety service using the users' device camera for incident monitoring in a blind spot with no CCTV coverage would be certainly more effective with a higher number of users. Apart from fulfilling the intended functionality, other factors could affect the adoption of IT services, thus influencing the success or failure of the corresponding systems. Haile and Altmann (2018) investigated the impact of interoperability in software services platforms

towards the decision for adoption by the users and found the lack of interoperability as a hindrance for adoption due to lock-in issues. The existence of applications' interoperability and data portability increases the utility of end users and increases the adoption of IT (Gebregiorgis & Altmann, 2015) and software services platforms. Interoperability in cloud federations also benefits the end users with the flexibility of porting data and applications even though it brings risk of replacement to the service provider (Haile & Altmann, 2015). However, this risk is not relevant in this study due to the non-financial objectives of the smart city information service providers.

Previous studies on the adoption of IT services have found a key role of the security of the ICT systems on the adoption decisions among individual users and organizations (Flavian & Guinaliu, 2006; Sin et al., 2010). The use of native language has also been found to increase the understanding and usability of the ICT services making application language an important factor affecting the adoption decision (Gudmundsdóttir, 2010). Based on the existing studies on the determinants affecting adoption decisions, a model is presented in the next section in order to investigate the citizens' preference in Islamabad city in Pakistan using discrete choice analysis.

5.2 Model

The attributes for the demand side analysis of information services that can impact the adoption of smart city services have been identified through a review of the existing literature. The identified attributes include language, access mode, service ownership, interoperability, security and cost. Language plays a significant role in the adoption of any service as it impacts the usefulness and understanding of the service and its contents (Ninsiima, 2015). Use of native language in eLearning systems has been found to improve the learning outcomes due to the ease of use of the system and clarity of the contents (Gudmundsdóttir, 2010). Two different options considered for the language variable are Urdu and English. Urdu, the national language of Pakistan, is spoken and understood all over the country and is expected to impact the choice of adoption by the citizens. On the other hand, English is also one of the official languages and is used in offices and is taught in schools as a mandatory subject. The delivery mode or the access mode of these services could be either through a web app or through native mobile applications developed for different operating systems like Android, IOS etc. This is required to investigate the users' choice towards the access mode for utility maximization (Bowen & Pistilli, 2012). End users would have a random choice towards the service provider, which could be the public sector, i.e., a government agency is controlling

the operations and management of the service, or the private sector where some of the services might be outsourced to the private sector or being operated in a public private partnership mode. This choice can be affected by the users' expectations (Hazlett & Hill, 2003) and their perceived satisfaction towards the services provided by the public or private sector (Mengi, 2009).

The interoperability amongst different services in smart cities defines the level to which these services can cooperate with each other in terms of data and information exchange and the flexibility of allowing processes to span multiple organizations (Nam & Pardo, 2011a). The interoperable services in a smart city can create a network effect which would potentially be helpful for the increased adoption of the services (Lee, Hancock, & Hu, 2014). Interoperability levels used in this study are technical, semantic and organizational as used by Novakouski and Lewis (2012) in a study on e-government interoperability. At the technical level, the applications are only able to exchange data and information but do not support the interpretation of this information which requires manual intervention. For example, a system could allow citizen uploading of a document needed while availing a public service; however, cannot interpret the document and it would be done by the person responsible. Semantic interoperability ensures that both the information and its meaning are exchanged between the applications eliminating the need for manual interpretation of this

information. The organizational level of interoperability supports processes that span different organizations. Security of the ICT systems is another important factor which can influence the adoption of a service (Pérez-Hernández & Sánchez-Mangas, 2011) and loyalty (Flavian & Guinaliu, 2006) of the individuals and the organizations (Sin et al., 2010) towards the service. For the security attribute, two levels are considered, i.e., basic and high. The basic level of security is supposed to ensure the confidentiality (Rodrigues, Sarabdeen, & Balasubramanian, 2016) of all the valuable information including personal data and financial information, whereas high level security means that additionally, smart city systems are protected against any kind of cyber-attack which could compromise the performance or availability of these services.

Finally, in order to analyze the price sensitivity of the citizens' choices; three pricing levels in terms of Pakistani Rupees have been used. These numbers have been established as 25%, 50% and 75% of the income tax applicable on the minimum tax slab by the Federal Board of Revenue (FBR) in Pakistan for the financial year 2018-2019. The different levels of these attributes, variables and the representative codes for use in estimation model are presented in Table 5.1.

Table 5.1 Information services attributes and corresponding levels

Attribute	Level	Variables	Dummy Codes	References
Language	Urdu English	Lang_U Lang_E	1= Urdu 0= English	(Ninsiima, 2015) (Gudmundsdóttir, 2010)
Access mode	Mobile app Web	AM_Mob AM_Web	0 = Mobile 1 = Web	(Bowen & Pistilli, 2012)
Service Ownership	Public sector Private sector PPP	SO_Pub SO_Prv SO_PPP	(Base case) 1 = Private sector 0 = PPP	(Mengi, 2009) (Hazlett & Hill, 2003)
Interoperability	Technical Semantic Organizational	I_Tech I_Sem I_Org	(Base case) 1 = Semantic 0 = Organizational	(Parameswaran & Chaddha, 2009) (Nam & Pardo, 2011b) (Lee et al., 2014) (Novakouski & Lewis, 2012)
Security	High Basic	Sec_H Sec_B	1 = High 0 = Basic	(Pérez-Hernández & Sánchez-Mangas , 2011) (Sin et al., 2010) (Rodrigues et al., 2016) (Flavian & Guinalíu, 2006)
Cost	500 1000 1500			50%, 100% and 150% of the lowest income tax slab. (Source: Ministry of Finance, Pakistan)
Choice		1= if chosen alternative 0=otherwise		
Demographics				
Education	High School, Bachelors, Masters			
Gender	Male, Female			

5.3 Methodology

5.3.1 Random Utility Model

Random utility theory focuses on the investigation of the choice made by individuals from mutually exclusive available alternatives (McFadden, 1974). It is based on the assumption that every individual is rational in making choices of the attributes and alternatives which can maximize his utility of the product or service. Another assumption is that the choice made by the individual is discrete, i.e., it is all or nothing and fractional quantities cannot be selected in the choice. Different types of preferences in discrete choice analysis have their theoretical foundations based on random utility theory. This study implies the assumption that the choice of alternatives having different level of the attributes for smart city services would be made by the end users in order to maximize their utility of these attributes which can influence the decision for adoption of these services. The random utility model for individuals making choices to maximize their utility (McFadden, 1974) is given as

$$U_{in} = V_{in} + \varepsilon_{in} \qquad (5.1)$$

Here, i represent the individual making the choice, whereas n denotes the alternative. Thus, U_{in} is the utility of individual i from alternative j. V_{in} is the part of utility observable by the researcher, whereas the stochastic part

of utility, which cannot be observed by researcher, is represented by ε_{in}. The respondent, while making a choice, compares his utility from all alternatives and selects the one for which his perceived utility is maximized. Therefore, the probability that the respondent will select alternative n from the alternatives available in the choice set can be expressed using the following equation (Train, 2009):

$$P_n = (U_n > U_j) = Prob\ (V_n + \varepsilon_n > V_j + \varepsilon_j)$$

$$= Prob\ (\varepsilon_n + V_n - V_j > \varepsilon_j \ \forall n \neq j) \qquad (5.2)$$

This shows that the probability of selecting an alternative increases if the difference in perceived utility between the chosen alternative and the compared alternative is higher.

5.3.1.1 Mixed Logit Model

The mixed logit model is an improvement over the standard logit model which incorporates random taste variation, unrestricted substitution patterns and correlation in the unobserved factor over time (Train, 1998; Train, 2009). In the standard logit model, taste coefficients are fixed, thus considering a homogenous behavior among the respondents over the choice profiles. The consideration of homogenous behavior of individuals will results in a constant error distribution over the unobserved factor of the

utility for the respondents and the choice attributes (Train, 1998). Similarly, as the mixed logit model does not exhibit the Independence of Irrelevant Alternatives (IIA) property, it allows general substitution patterns. In contrast to the standard logit model, the correlation in the unobserved factor over time can be accommodated through t choice situations being offered to the respondent.

If the individual i has N choice alternatives where ($n \in N$) then the utility of the individual i for the alternative n is given by the equation.

$$U_{in} = \beta_i' x_{in} + \varepsilon_{in} \qquad (5.3)$$

Here, x_{in} are the attributes of the choice alternatives for the respondent and β_i' is the resultant coefficient vector of these attributes for the respondents. The assumption in mixed logit model is the variation of these parameters across the respondents while following a specific probability distribution, therefore accommodating the random taste variation across the respondents. The respondent selects a choice out of the available choices in order to maximize his utility, thus generating his own values of β and ε. Therefore, the probability distribution can vary across the respondents and the attributes of the available alternatives. Normal distribution is the most widely used, however, for attributes like pricing, where coefficients will take a negative sign for all respondents, as no one wants to pay more, either

a lognormal distribution can be used or it can be kept fixed in the estimation. According to Train (2009), the probability of alternative n to be chosen over k number of β can be obtained with the equation

$$P_{in} = \int \left(\frac{e^{\beta_i' x_{in}}}{\sum_k e^{\beta_i' x_{ik}}} \right) f(\beta) d\beta \qquad (5.4)$$

5.3.2 Willingness to Pay

The willingness to pay method is used in consumer pricing analysis and measures the maximum amount a user can pay for availing a service or acquiring a product. WTP has been used to detect price sensitivity for the choices made by the citizens towards the attributes smart city services, which can be the predictor of adoption of the service given those attributes. WTP measurement can be accomplished through revealed preferences or stated preference for estimation of the user's choice (Breidert, Hahsler & Reutterer, 2006). Revealed preference uses market observations to obtain consumers' pricing preferences, however as this research is conducted through a direct survey, it is well suited for the use of stated preferences. In this discrete choice analysis for the citizens' preference of information service attributes effecting their decision of adoption; WTP would provide the relationship between the changes in attribute levels to the change in price. While there may not be any direct cost associated with smart city

services, the actual expenditure has to be undertaken using public money, which is generated by the citizens in the form of taxes. It is therefore important to consider the individuals' utilities towards attribute levels and their corresponding pricing preferences. The mathematical representation of the WTP estimation is the ratio of the marginal utility of the attribute to the marginal utility of cost (Train, 2009).

$$WTP = \beta_{xi} / \beta_{cost} \qquad (5.5)$$

Here, β_{cost} is the coefficient of the cost attributes and β_{xi} is the coefficient of the selected attribute to estimate the price sensitivity.

5.4 Survey Design and Data

5.4.1 Survey for Discrete Choice Analysis

Using the attributes and their levels from Table 5.1, orthogonal choice profiles were generated using SPSS software. Orthogonal choice profiles are generated due to the large number of profiles in a full factorial design which is not practical to be presented in terms of choice cards to the respondents. Orthogonal designs are commonly used to cater for the complexity of a full fractional design. One problem with this method is that the orthogonal designs grow rapidly, as the number of levels of attribute are increased, however, in our case the maximum number of attribute levels are

three making orthogonal choice profiles a suitable choice. The orthogonal choice profiles generated using SPSS are given in Table 5.2.

Table 5.2 Choice profiles

Card ID	Language	Access Mode	Service Ownership	Interoperability	Security	Cost (PKR)
1	Urdu	Web	Public Private Partnership	Technical	High	1000
2	Urdu	Mobile app	Public Sector	Technical	Basic	500
3	English	Web	Public Sector	Technical	Basic	500
4	Urdu	Mobile app	Private Sector	Organizational	High	500
5	English	Mobile app	Public Sector	Semantic	High	1000
6	Urdu	Web	Private Sector	Technical	Basic	1000
7	English	Mobile app	Public Private Partnership	Technical	Basic	1500
8	English	Mobile app	Public Sector	Organizational	Basic	1000
9	English	Web	Private Sector	Semantic	Basic	500
10	Urdu	Mobile app	Public Sector	Technical	High	500
11	Urdu	Web	Public Sector	Organizational	Basic	1500

12	English	Web	Public Private Partnership	Organizational	High	500
13	English	Mobile app	Private Sector	Technical	High	1500
14	English	Web	Public Sector	Technical	High	500
15	Urdu	Mobile app	Public Private Partnership	Semantic	Basic	500
16	Urdu	Web	Public Sector	Semantic	High	1500

These 16 choice profiles or alternatives were presented to the respondents in the form of choice sets. There were a total of four choice sets, each of which contained four alternatives. Respondents were asked to choose one alternative from each choice set which maximizes their utility of the smart city information services while considering each choice set independently.

These choice profiles contained different arrangement of the levels of attributes considered in the study. While choosing an alternative, citizens would have to make a tradeoff decision between two or more attributes. Therefore, the choice of an alternative by the survey respondent can help identify his utility towards the attribute levels. A sample choice card is presented in Table 5.3.

Table 5.3 Sample choice card

	Package 1	**Package 2**	**Package 3**	**Package 4**
Language	Urdu	Urdu	English	Urdu
Access Mode	Web	Mobile App	Web	Mobile App
Service Ownership	Public Private Partnership	Public Sector	Public Sector	Private Sector
Interoperability	Technical	Technical	Technical	Organizational
Security	High	Basic	Basic	High
Cost	1000	500	500	500
Choice				

The survey was conducted online in order to obtain responses from the citizens in Islamabad city in Pakistan, which is in the early stage of smart city development. Respondents were asked to go through a description before moving on to the question section, which contained the introduction, context of the survey and details about the attributes and their levels in order to give participants a clear understanding of the choice situation. The complete responses from 155 citizens were received and were included in the estimation process for the discrete choice analysis. The demographic information of the respondents is presented in the Figure 5.1 and Figure 5.2. Stata 12.1 software was used for the estimation of the mean coefficients, WTP estimates and the individual beta values.

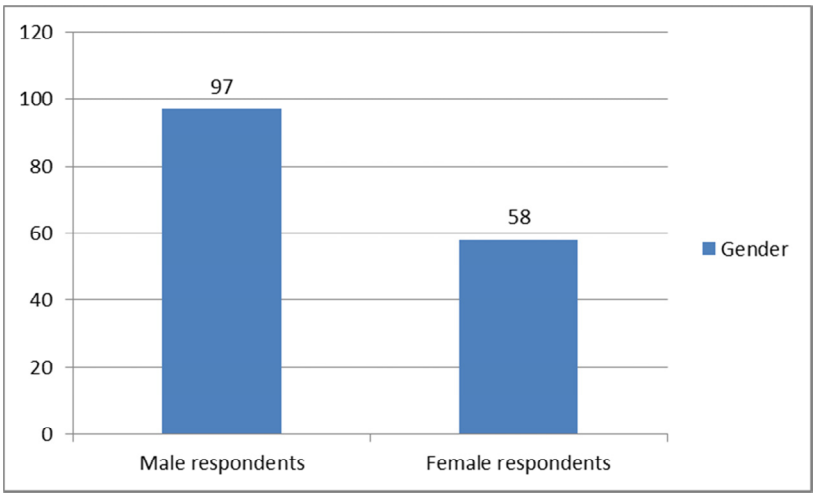

Figure 5.1 Gender based distribution of respondents

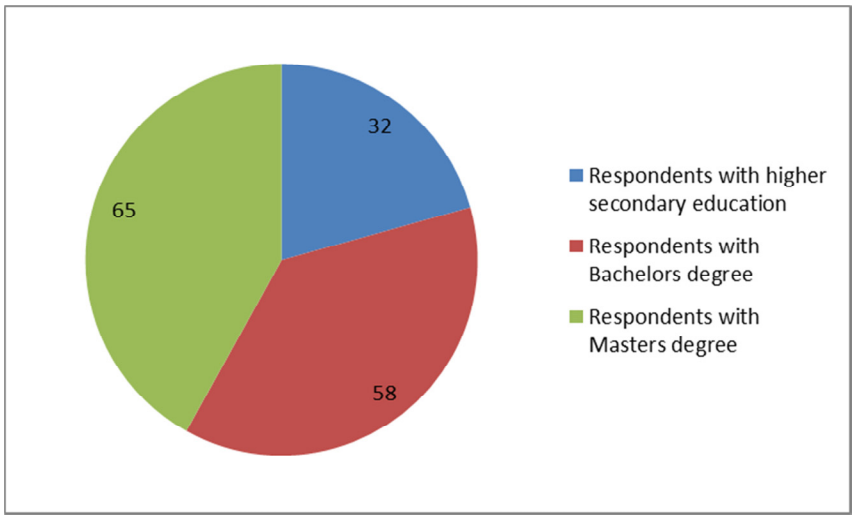

Figure 5.2 Education level of respondents

5.5 Estimation of Results

As mentioned earlier, all the citizens would behave differently to make the choices of the levels of the attributes in order to maximize their utility of

the smart city services. The utility function modeled based on Equation (5.3) considering these attributes levels is as given in the Equation (5.5).

$$U_{in} = \beta_{Lang\_U} x_{Lang\_U} + \beta_{AM\_web} x_{AM\_web} + \beta_{SO\_prv} x_{SO\_prv} + \beta_{SO\_ppp} x_{SO\_ppp} + \beta_{I\_sem} x_{I\_sem} + \beta_{I\_org} x_{I\_org} + \beta_{Sec\_h} x_{Sec\_h} + \beta_{Cost} x_{Cost} + \varepsilon_{in} \quad (5.5)$$

Here, U_{in} is the utility of individual i for the choice of alternative n. x_{Lang_U} is a dummy variable which represents the use of Urdu as the language for these services. All other variables are consistent with Table 5.1. In case of service ownership, the public sector has been kept as the reference variable, whereas technical interoperability is the base case for the interoperability. Cost was considered as fixed which means that WTP follows the distribution of the attribute for which WTP is estimated.

The estimation results obtained using the mixed logit model are presented in Table 5.4. Stata 12.1 software was employed and maximum likelihood was used for the estimation of the coefficients (Hole, 2007). The significance level of the mean coefficient and standard deviation are listed with their corresponding values.

Table 5.4 Estimations using mixed logit model

Variable	Mean	Standard Error	Standard Deviation	Standard Error	WTP
Cost	-0.0004***	0.0001			
Urdu	-0.5586***	0.1434	1.0652***	0.1913	-1436.7542
Web	-0.1867*	0.1091	0.4491*	0.2512	-480.2493
Private Sector	-0.2334	0.1514	0.6052**	0.2864	-600.3199
PPP	0.1134	0.1344	0.7372***	0.2133	291.6500
Semantic	-0.1967	0.1250	0.1651	0.398	-505.9721
Organizational	-0.6833***	0.1762	1.0077***	0.2833	-1757.5467
High	0.2310**	0.1076	0.5596**	0.2251	594.1478

*** Significant at 1%, ** Significant at 5%, * Significant at 10%

The mean coefficient of cost is -0.0004 with a significance level of at 1%, showing the negative utility of end users towards cost. The use of Urdu language has a mean coefficient of -0.5586 and is significant at the 1% level. This highlights the negative utility of the Urdu language for the users. The standard deviation for Urdu is 1.0652 with a significance level of 1%, which shows that the choices are heterogeneous. The preferred access mode was using a mobile app as depicted by the negative coefficient of

web, i.e., -0.1867. However this result was only significant at the 10% level. The mean coefficients of public private partnership and semantic interoperability were also not significant. Organizational interoperability is found to be significant at the 1% level with a mean coefficient of -0.6833, thus demonstrating a negative utility of the respondents. Similarly, the high security mean coefficient is also significant at 5% with a value of the mean coefficient of 0.2310. It is obvious that people have a positive utility towards higher levels of security. The standard deviation for high security is 0.5596 with a 5% significance level, displaying the heterogeneity of choices among the citizens for this attribute. The last column of Table 5.4 shows the WTP estimates providing the price sensitivities of the citizen's choices.

The interaction of demographic variables like gender and qualification is shown with the security level and the language. It is clear from Table 5.5 that the increase in qualification of the respondents increases their utility towards higher levels of security. Moving from higher secondary to master degree carries a positive utility towards a high security level. Similarly, male respondents were found to have positive utility for high level of security. It means that they are more concerned about the availability and performance of the services as well apart from just the security of their data and transactions. Both of these attributes were significant at 5% level. The standard deviation for both of these attributes shows the heterogeneity in

the choices and was significant at 10% level. Interaction of the gender attribute with the choice of language was not significant. Similarly, moving from the higher secondary education to the bachelor's degree also did not show any significance for mean coefficient's value.

Table 5.5 Demographic interaction

Variable	Mean	Standard Error	Standard Deviation	Standard Error
Cost	-0.0004***	0.0001		
Urdu	-0.3409	0.2274	1.1622***	0.2656
Web	-0.1740	0.1139	0.5112**	0.2514
Private Sector	-0.2933*	0.1667	0.7828***	0.2643
PPP	0.1299	0.1384	0.8321***	0.2134
Semantic	-0.2298*	0.1368	0.4496	0.3288
Organizational	-0.7470***	0.1883	1.1956***	0.2950
High	-0.5373*	0.3182	0.0253	0.3645
Urdu_Male	-0.3857	0.2912	0.4021	0.5908
High_Male	0.4988**	0.2297	0.5222*	0.3109
High_BS	0.3857	0.3428	0.3995	0.4060
High_MS	0.6782**	0.3432	0.5737*	0.3165

*** Significant at 1%, ** Significant at 5%, * Significant at 10%

Citizens have different level of perceived importance towards different attributes, which would affect their choice of alternatives while making a selection. It is important to know which attributes citizens placed more importance on while making the choice of the alternative. Using the following equation from Shin, Woo, Huh, Lee, & Jeong (2014), the relative importance of these attributes has been calculated through the part worth utilities for these attributes.

$$RI_K = \left[\frac{(part-worth_K)}{\sum_k (part-worth_k)}\right] * 100 \quad (5.6)$$

The individual-level beta values of all 155 respondents were estimated by taking 500 Halton draws (Train, 1999) to calculate the part worth utilities from these beta values. The relative importance of all the attributes is given in Table 5.6. The attribute that was given most importance by the respondents was interoperability followed by language.

Table 5.6 Relative importance of attributes

Attributes	Relative Importance (%)
Language	28.12
Access Mode	8.23
Service Ownership	21.4
Interoperability	31.1
Security	11.11

Chapter 6 Discussion and Conclusion

6.1 Discussion and Implications

The contribution of this study is to provide guidelines to smart city planners who are in the process of initiating smart city implementations. This research focuses on the analysis of the intellectual components based on the subjective judgments of experts along with an analysis of the demand side perspective.

The study on the role of human capital determinants towards the success of smart city implementation suggests that experience, education and R&D culture are the components having the most dominating attributes as per the experts' opinion. The overall results show that the difference of priority is very small for the top-three highly ranked attributes, i.e., domain specific tacit knowledge, multi-disciplinary scope of education and the number of R&D personnel. These three characteristics jointly form the nexus of education, experience and research, which is mandatory for smart city development. It also shows the importance of academia-industry collaboration, which is a key element of the triple-helix-model of the university-industry-government role in smart city development (Leydesdorff & Deakin, 2011). New innovative solutions for urban issues can be developed through the combined efforts of the industry and the

academic research community. The coordinated approach for the development of solutions for smart cities will also help in harmonizing the view of smart cities among the two groups. The experts' opinion towards human capital components, by assigning creativity much higher than imitation, clearly depicts their preference towards a leading role in smart city development, which means that just the replication of existing solutions is not their choice. The implementation of existing solutions can be influenced by propriety solutions from vendors like IBM or Cisco. However, this could cause vertical and horizontal interoperability issues among the smart city systems depending upon the chunk of services outsourced to different vendors. However, a custom-built solution through innovation can ensure interoperability by using a coherent approach and standardization. It will increase the integration capabilities of these systems leading to a more efficient smart city implementation. Thus, the results are in harmony with the ideology of the triple-helix-model for innovation in a smart city. ICT specialist/system developer skills have been ranked higher than the ICT user skills, giving less priority of ICT skills of users of system, which again indicates the preference towards smart city solution development. Social factors like ethnic plurality or life expectancy are also not seen as critical components for the considered goal.

The respondents expressed the highest preference for the tacit knowledge, which depicts the need for a high concentration of experienced persons.

The complex nature of city systems and their interdependencies requires the existence of experiential knowledge for developing and designing smart city systems and processes. Tacit knowledge is vague and thus difficult to codify. It is acquired thorough personal experience and exchanged through the interactions amongst the involved persons. As it is very helpful in making critical decision during the planning and execution phases, the acquisition of tacit knowledge is highly important in the smart city development process either through the employment of individuals or through consultancy. However, this is a problem in developing countries, where experienced persons with tacit knowledge are not abundant. As tacit knowledge cannot be taught and can only be learnt (Bajracharya & Roma, 2006) through interaction, it is therefore necessary to ensure the maximum knowledge spillover by creating a supporting social culture and processes. The promotion of internship programs to groom the upcoming workforce and collaboration culture is a possible policy directive inferred from this finding.

The finding of study is supported by Leydesdorff and Deakin (2011) who advocate that discipline-based knowledge will eventually become obsolete and has to be replaced by techno-scientific knowledge that is generated through multi-disciplinary projects. The OECD learning framework 2030 (OECD, 2018) discusses disciplinary knowledge as the raw material from which new knowledge is developed and stresses the importance of thinking

beyond disciplinary boundaries. Smart city implementation requires technological solutions to be developed at the cross-section of different systems which entails nurturing a workforce with a multi-disciplinary education. Smart city implementation requires knowledge across computing, engineering, social and management sciences. Policies should be devised by the government to promote multi-disciplinary education that can be undertaken by offering scholarships for such educational programs and giving priorities in funding projects proposed across multiple disciplines.

The development of a R&D culture is another important aspect as a higher number of researchers would lead to more investigative findings and development of innovative technological solutions to the urban problems. Universities are a good playground for research-related activities for R&D capacity building, experimentation and testing of new ideas, thus, channelizing funds to universities in a way to fuel the smart city development process will help create a valuable human capital. The development of smart city labs by the smart city authority in coordination with universities will provide a platform for collaborative research targeted to finding solutions for the city's issues. Tsai and Hung (2014) agree that the investment in R&D personnel will help create a human force, abundance of which will play a significant role in technology maturity. Thus, the finding is reliable as smart city development has its foundation in

the role of technology integration in the urban function. Therefore, policy makers' focus should be placed on increasing the number of R&D personnel in both academia and industry. This could be promoted by providing incentives like tax rebates.

Second, the study on exploring the structural capital elements with respect to their importance towards the smart city implementation success pinpoints the critical focus areas. Infrastructure was ranked as the most important category of the structural capital elements, depicting the critical nature of the ICT infrastructure for smart city development. Communication and information systems are the mandatory requirements for the digitization of urban physical infrastructure and the infusion of automation in the urban processes in order to bring about efficiency. The stated preferences of the experts do not reflect a big gap between the priorities of communication and information systems, which shows that both of these elements are almost equally critical. Internet of Things is main pillar for smart city development purposed to create the virtual replica of physical objects which requires the penetration of a robust and affordable communication system. The fixed broadband penetration has been given very low priority, depicting the need for mobile connectivity either through mobile broadband penetration or the provisioning of public Wi-Fi. Public Wi-Fi came out to be the most important factor under the communication system category, which is in line with the findings of

Saberi (2015) who investigated the impact of community Wi-Fi on the urban digital divide. Urban areas being pockets of inclusion and exclusion can use public Wi-Fi to extend the connectivity to disadvantaged communities. This is also consistent with the growing use of smart phones and indicates the potential need for services access during mobility, realizing which led many of the smart cities to offer free public Wi-Fi service to their citizens (Hwang & Choe, 2013; Arup, 2010; Liu & Peng, 2014). The interpretation of this finding suggests a lesson for city planners to use public Wi-Fi as tool for attracting citizens to digital services apart from improving the broadband infrastructure. This argument is supported by the finding of Schumann and Stock (2015), where the use of U city information services in Oulu, Finland was higher with the provisioning of public Wi-Fi than the installed touch screens. A higher number of users using the smart city services will results in an effective and efficient utilization of these systems.

The role of information system in the smart city helps in distinguishing between digital and smart cities, where a smart city automates the scenarios and perspectives instead of just fetching data. Therefore, the information system under the infrastructure category, even though ranked number 2, has got a priority which is very close to that of the communication system. Experts are of the view that development of new programs and services is more beneficial to ensure robust smart city systems as compared to the

integration of existing information systems. The takeaway is to design the information systems with the capacity of vertical and horizontal integration capable of fulfilling the industry 4.0 needs (K Zhou, Liu, & L Zhou, 2015) of interoperability. The development of such programs under the smart city umbrella will help to increase the interoperability of these systems and a better management, integration and use of the data acquired from these programs.

In the data orchestration component, open data was given the highest priority, which is in line with the growing popularity of the open data model. Open data, while ensuring the transparency of governance, also helps in open innovation where individuals can use the data to develop innovative services. Although implementing the open data model can bring about transparency and an improvement in services, extra care should be taken in the policy, procedure, and data selection and specifications to minimize the risks involved in terms of security of infrastructure, privacy, and misinterpretation of data (Kucera & Chlapek, 2014).

The category which was ranked second was ‘process’ comprising the policy, development method and management and control. Policy was the dominant component of this category as per the experts’ opinion under which local level policies acquired higher priority. Considering the local scope of the smart city development, the higher weightage to the local level

policies shows that the metropolitan government plays a key role in the success of the smart city development. The innovation growth policies devised and enforced at the metropolitan level fuel the innovation activities in the city that can contribute to the smartness of city in a bottom-up approach by providing new mechanisms and applications for addressing urban issues. On the other hand, knowledge generated from innovation activities and the developed skillset can be used during the planning, implementation and management phase of smart city systems in case of a top-down approach. The local government should therefore devise policies for innovation generation along with the focus on promoting collaboration amongst the different stakeholders like citizens, public sector and industry (Nam & Pardo, 2011a). The development method and management and control have a substantial difference of priority from the policy component, representing the very low relative importance of these components. Although the 'relational' category acquired very low priority, under this category, citizen engagement was the dominant component. Citizen engagement has been practiced by many smart cities either through the living lab model or by obtaining direct opinion through polls for bridging the gap in understanding of a future service between the ideas of the policy makers and the expectations of the citizens.

The overall priority weights puts the local level polices at the top, followed by the development of new programs, public Wi-Fi, open data, etc. There is

an important lesson for the city governments aspiring to transform their infrastructure and systems towards smart city model to put special focus towards the development of policies and their enforcement that strengthen the necessary ingredients for smart city development like innovation generation and the skilled human capital. The open data model for digital cities will provide new opportunities for developers to come up with creative solutions to urban issues. Similarly, the provisioning of Wi-Fi to the citizens will help in digital inclusion, eventually increasing the users of smart city services. Public Wi-Fi initiatives have been adopted by different cities like Lahore, Islamabad, Seoul, Melbourne etc. Similar to public Wi-Fi which is a good incentive for citizen's access to smart city services, a higher penetration rate for mobile broadband is also critical. Along with providing the end users with internet access, it is needed to connect devices which are installed either for data sensing or displaying information as not all the devices could be suitable for providing fixed-line access, examples of which are devices for supply/fleet management, sensors in retail business for inventory management and tracking etc. The study did not consider short range communication systems like Bluetooth and RFID that have a local scope of implementation.

The strategy agenda items based on the results are presented in Table 6.1, which provides the key focal areas and points to be considered in smart city implementations. Standardization ensures the ease of integration and

interoperability among different systems. In case of a bottom-up approach, where the implementation projects are carried out in isolation, the use of commonly agreed-upon standards will prevent any lock-in issue at the data and application level. It is suggested to develop system interfaces that can be utilized by any other agency that intends to implement process-level integration. The co-creation model supports the exploitation of community intelligence and platforms for R&D and entrepreneurial activities for the filtering of ideas and their commercialization. While joint efforts of the smart city authority with universities and R&D centers help utilizing their R&D potential to develop solutions for city problems, citizen engagement using civic innovation centers provides opportunities for benefiting the citizens' skill sets along with bridging the gap between the service providers and the end users. Development of incubation centers and offering of smart city projects to young startups would encourage entrepreneurial culture, which will fuel innovation and economic growth as well. Openness of data creates opportunities for open innovation that leads to economic growth. It also facilitates the transparency of the governmental operations and functions. Individual developers and businesses can use the data for decision making and for the development of new applications and services.

Table 6.1 Strategy agenda items

Strategy Agenda Items		
Standardization	Consistency across agencies and projects	Process integration System interfaces for integration ease
Co-creation Model	Engagement of citizens	Civic innovation labs by smart city authority Bridging gap between service provider and users
	Promotion of start ups	Incubation center setup Offering of smart city projects
	Engagement with universities	Source of Innovation Interdisciplinary/management & policy research Bridge the gap in academia and industry view of smart city
Inclusion	Bridging the urban digital divide	Inclusion of economically disadvantageous communities
Openness	Openness of data	Community Innovation Transparency of government functions

Finally, the analysis of the demand side perspective for the case of Islamabad provides very useful insights for city planners that would be helpful in better planning of smart city systems. It was observed that users

have a negative utility for the use of Urdu as a language used in application programs for smart city services. While the variance shows heterogeneity in the choice of language by the users, still, the majority of the respondents prefer to use the English language. This could be due to the fact that the English language is taught to students in Pakistan as a mandatory subject and the city of Islamabad has a much higher literacy rate (87%) than the country average (58%). However, it puts a limitation on this finding as it cannot be generalized to the other cities in Pakistan with a lower literacy rate. Likewise, the coefficient of cost was also negative, depicting the negative utility of users towards cost, which makes sense as nobody would like to pay a higher amount.

With the existence of heterogeneity, the preferred access mode for users (66%) is mobile with native mobile apps which is consistent with the growing number of 3G/4G subscribers (~60 million, Source PTA[2]) having higher penetration rates in the urban areas as compared to rural areas. This trend shows the increased inclination of the citizens towards the use of native mobile apps, which can be useful in planning and developing the user side of smart city services. However, the existence of heterogeneity shows that some people still want to use web apps as the access mode for these services. This indicates the existence of a divide in the city for the use

[2] https://pta.gov.pk/en (Pakistan Telecommunication Authority)

of smart phones, either due to the digital divide in broadband access or access to the smart phone which requires further investigation.

The coefficient for interoperability attributes was significant for organizational interoperability only. Heterogeneity in the choice of organizational interoperability depicts the difference of opinion amongst people. While the majority of the people prefer only technical interoperability, which gives them control of their actions and transactions, there is a user community which has a positive utility for the organizational-level interoperability. This could also be an indicator of the lack of understanding of the interoperability of smart city services by the end users. While users prefer not to move towards organizational interoperability, it lies at the foundation of smart city development which calls for actions to be taken to enhance the community's understanding towards smart city services and their corresponding benefits like convenience and increased quality of life.

The observation on the security attributes shows a positive utility of users towards higher security. This was highly expected, as people not only want their data and transactions to be secure, but the availability of the services and the performance should be consistent and robust. The finding of users' demand of high security suggests the development of a strong legal

framework and of a cyber-response force to take care of cyber security incidents, which is currently lacking in Pakistan.

The estimation of WTP shows that the choices of language interoperability and security are highly sensitive to cost. People are willing to pay more if a high level of security is ensured, making it an important attribute to be considered for increasing the adoption rate. Similarly, people are less likely to pay if Urdu is being used as the language, which is a favorable condition for the development of services as the existing information systems and software development community primarily use the English language.

The overall findings of this study suggest focusing on the security aspects of the smart city services in Islamabad in order to ensure rapid adoption along with community awareness towards the interoperability of the smart city services.

6.2 Conclusion

While smart cities are a global topic of interest, the need was observed for the exploration of intellectual capital components' role in smart city implementation. This research focused on the inspection of intellectual capital resources in the context of smart city implementation success in order to support the planning and development phases. This research has used a multi-dimensional approach to human capital in order to capture the

experts' preferences for the components which play a key role for smart city development success. Cities are becoming centers of economic growth driven by innovative human capital. Human capital components have been divided into four different categories considering individual-level traits like personal qualification, personal traits and collective characteristics like culture and social factors. The experts' preferences put the category of personal qualification at the highest rank. The overall priority weights estimation for the attributes assigns the first rank to the domain specific tacit knowledge followed by the multi-disciplinary scope of education. The components of behavior, social security, and ethnic plurality were amongst the attributes having the lowest ranks. The study provides valuable insights by identifying the critical human capital components and is useful for making policy decision.

The multi-criteria decision making technique used for the analysis of structural attributes lays the foundation for further research in this area, along with contributing to policy and planning decisions. The outcome of the study is useful for policy makers during the early stage of smart city development, who should devise comprehensive policies at the metropolitan level to foster innovation and inclusion while focusing on the development of communication systems. The enforcement of the open data model is suggested, which would trigger the use of this data to further refine the urban processes and the development of innovative applications.

The study supports the development of new services through the engagement of the end user community, so that the adoption rate and success rate of these services increases along with the increased interoperability amongst different systems. These structural arrangements suggested by the study are irrespective of the type of service being developed under the smart city model. Whereas different smart cities considered in this research have used different orchestration of these structural elements, it provides a baseline for policy makers attempting to initiate smart city projects for the management of urban function and resources with the use of information and communication technologies.

The discrete choice analysis of the citizens' preferences in Islamabad provides valuable insights into the demand side expectations for smart city services. Security of the smart city systems is one of the important aspects that can influence the adoption rate of these services, providing the planners and developer of smart city with a critical success factor. It is required to safeguard the data and availability of these services to ensure robustness along with proving a legal framework and cyber security support structure and response force to win the trust of the end users. The need has been observed for the awareness of interoperability among smart city systems and services to the citizens who do not exhibit a higher utility towards interoperability.

In summary, this research has targeted a very important aspect of smart city development which was still underexplored in the extant literature. Apart from the contributions regarding the relative importance of intellectual capital attributes and the corresponding policy implications, the disagreement among the respondents from academia and industry highlights the need for bridging the gap between the understanding of smart city intellectual capital resources in academia and industry. While the demand side study serves the intended purpose to support policy decisions for the development of smart city services in Islamabad, the study can be extended to include participants from different geographies in order to explore a cross-city perspective, so that the results can be generalized and correlated to the local contextual attributes.

6.3 Limitations and Future Work

This dissertation focuses on the role of intellectual capital components in the implementation of smart city systems. The outcome of the research provides a comparative significance of the attributes of intellectual capital components that can be utilized to make policy and investment decisions. However, different cities could be at a different level of infrastructural development and thus also their progress of smart city implementation would not be uniform. The difference in the infrastructural development between cities can be related to both physical as well as logical

infrastructure. The broadband infrastructure or penetration rate can vary across different cities. Similarly, some cities could be initiating the digitization of organizational processes within the government agencies, whereas other cities may already have information systems implemented in the organizations. Therefore, the maximum benefit from the findings would be applicable to cities at the early stage of smart city development. The bigger beneficiaries would be the planners and policy makers in the developing countries, who are now following the trend of smart city development and are initiating smart city projects. In a scenario where the smart city umbrella utilizes the existing services deployed at the participating organizations/agencies, interoperability issues will be raised due to the potentially different data formats and nomenclature, non-standard implementations, and utilization of the programming frameworks with no interoperability. It might create hindrance in using this data for cross sector data analytics along with preventing the digitization of the cross agency processes. However, the shift towards the implementation of interoperable information services and solutions would require more resources, creating additional burdens in terms of effort and finances.

The case of investigating the factors affecting the adoption of smart city services for Islamabad provides results which might not be directly generalized for the other cities. This is due to the different contextual properties which could vary across different cities and thus call for a cross

city study in Pakistan. The literacy rate for Islamabad is much higher than the country average which could impact the citizen's choices towards the attributes presented. Further, the diffusion of information and communication technologies including broadband penetration, adoption of smart phones and the corresponding competencies to benefit from these technologies would be highly different than the other small cities. However, the study provides with useful information for smart city projects in Islamabad along with the baseline for extending this research to include the other cities.

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Appendix A: Description of Attributes for AHP Survey

	Human Capital		
	Component	**Indicator**	**Description**
Personal Qualification Individual's qualification includes the education level, scope, digital literacy and experience.	**Education** Level and scope of the education attainment by the workforce	Level of education	Level of education attained by the human resource i.e. primary, secondary, tertiary level education
		Multi-disciplinary scope of education	The scope of education includes multiple disciplines nurturing capabilities of solving interdisciplinary problems.
	Digital Literacy Level of the ICT skills of the workforce	ICT User Skills	ICT user skills include adequate knowledge of using ICT technologies including devices, information systems, access and navigating portals at offices and for personal matters.
		ICT Specialist Skills	ICT specialist skills including capturing, codification and analysis of data and information, command on deep technical concepts and tools, creating new innovative applications for civic management and problem solving. Capability to make decision through data analytics etc.
	Experience Existence of relevant experience.	Domain specific tacit knowledge	Accumulation of specific tacit knowledge through work experience which is ready to be disseminated and leveraged. It is years of relevant experience
		Learning by doing	Experiential learning by doing the tasks which include trial, fail and success approach in the absence of relevant experience
Personal Traits Individual's personal qualities like creativity, motivation, adaptability etc.	**Intellectual Agility** Individual's intellectual capabilities	Creativity	Ability to generate new ideas, solutions to the problems and out of the box thinking in known and unknown problem scenario.
		Imitation	Ability to replicate the existing solutions, programs, and processes, in order to increase efficiency and productivity.
		Adaptability	Ability to quickly adapt to a different environment, team, and job task without compromising the productivity and motivation.
	Behavior Behavioral characteristics of the workforce	Motivation	Motivation level to accomplish the task.
		Commitment	Engagement and commitment level of the employees to their job.
		Teamwork	Capabilities and willingness for collaborative teamwork for increased productivity.
		Leadership	Leadership capabilities of the workforce
Culture Existence of the learning, R&D and	**Lifelong Learning** Continuous learning and improvement of	Formal Learning	Skills improvement of employees by themselves or a firm through on site or off site training directly related to job or self-improvement of individual for career prospects.

business tendencies in the population.	skills	Self-Regulated Learning	Self-Regulated learning is the improvement of skills through available resources in print and electronic format including organized resources like MOOCS or scattered like short lectures
	Entrepreneurial Culture Tendency towards business startup	Density of enterprises	Number of firms per 1000 population. It depicts the volume of enterprises accounting for survival rate of startups.
		Density of enterprise birth.	Number of new firms established per 1000 population. It indicates the startups being established.
	R&D Culture Individual, Govt. and industry tendency towards R&D	R&D Expenditure	R&D investment done both in academic and industry environment.
		R&D Personnel	No of Researcher/R&D personnel both in academia and industry.
Social Factors Ethnic mix of workforce and life expectancy.	**Life Expectancy**	Life Expectancy	Life expectancy of the residents at birth.
	Social Security	Social Security	Existence of social security programs for population like income maintenance and old age benefits.
	Ethnic Plurality Ethnic mix of the workforce	International students	Number of International students studying in the metropolitan academic institutes of higher education.
		Skilled Immigrants	Number of skilled immigrants working in the city.

Structural Capital			
Dimensions	**Components**	**Indicators**	**Description**
Process Process component of the structural capital includes development method, management mechanism and policy.	**Development Method** Smart city development approach being used. Top-down or bottom-up approach.	**Top-down approach**	Top down approach starts with the overall planning of the smart city development considering the services, their scope, interaction, participating and potential collaborating organizations leading to the implementation and operation phase.
		Bottom-up approach	Bottom-up approach starts with existing services integration and continuous integration of new services as developed into the smart city platform working either in centralized or decentralized mode.
	Management & Control Smart city management and control mechanism either centralized or decentralized.	**Centralized Management**	There is only one integrated smart city control center that manages all of the service related to smart city and responsible for collecting the generated data, its storage, ownership and dissemination to the respective users.
		Decentralized Management	All of the organizations work in autonomy and manage their own control center for smart city services. The collaboration and information/services sharing between organizations occur whenever needed in direct communication.
	Policy Existence of National and/or local level	**National Policy**	Existence and impact of a national level policy attributes like funding, taxation and privacy laws regarding individuals and data.

	policies for smart city.	**Local Policy**	Local level policies for smart city development like innovation growth policies, public private partnership in projects etc.
Relational Relational component of the structural capital includes citizen engagement level and organizational cohesion.	**Citizen Engagement** Citizen's engagement level in decision making/ improvement	**Citizen Engagement in Decision**	Citizen engagement in the decision making process of the development of new services, applications and projects targeted to address community issues.
		Post development feedback	Post development feedback is the user's feedback/complaints through the smart city support center provided through phone, app or portal that helps in refining the services.
	Organizational Cohesion Mode and density of communication between organizations	**Horizontal Communication**	Horizontal communication mode involves direct communication between the peering organizations without the need of a central authority or integrated control center.
		Vertical Communication	Vertical communication occurs amongst the collaborating organizations through smart city authority.
Infrastructure Infrastructural dimension of the structural capital comprises communication system, software and databases related attributes.	**Communication System** Status of communication system use	**Fixed Broadband**	Fixed broadband penetration
		Mobile broadband	Mobile broadband penetration
		Free Wi-Fi	Provisioning of the Free Wi-Fi to citizens at the public places
	Information System Approach for use, integration and development of information systems	**Utilization of existing information systems**	Existing information systems at the participating organizations are utilized, with modification if needed, into the smart city operating system. Reduces the development effort and beneficial in utilizing user's existing operating skills. There however could be interoperability issues.
		Development of new Information systems	Development of new information systems and programs specifically designed to be used for smart city operating systems. While it increases the development efforts, the resulting system is more robust and efficiently integrated.
	Data Orchestration Databases management and availability approaches	**Central Data**	Central data storage at the smart city authority with ownership and decision right for data provisioning
		Open Data	Open access to the data gathered in smart city services amongst organizations and for the citizens
		Data Sharing Protocol	Enforcement of a data sharing protocol amongst the participating organizations and between organizations and smart city authority.

Appendix B: Survey Questionnaire for AHP

This survey is intended to prioritize the elements of human capital and structural capital with respect to their importance towards smart city implementation success. The concept of smart city used in this study employs the use of Information and Communication Technologies (ICT) to optimize the urban management processes and functions like mobility, environment, healthcare, citizen safety, governance, energy management and emergency response etc. The successful smart city implementation brings efficiency to the urban processes and services along with ensuring sustainability.

Section A:

This section requires your opinion in ranking the elements of the human capital in terms of their importance towards the success of efficient and sustainable smart city implementations. In a pairwise comparison, please record your response as given in the example before the questions.

Human Capital:

Human capital is a production element for increased performance and innovation at the firm, city, regional and national level. Rapid diffusion of information and communication technologies and emergence of knowledge intensive industries have driven the investigative studies on human capital measurement to identify the value sources in workforce capabilities. Role of human capital in smart city implementations is critical due their inherent objective to use ICTs in providing cross sector solutions, to the issues raised by the rapid urbanization, while ensuring the continual innovation. The objective of this study is to identify and rank the critical elements of human capital based on their importance to the success of smart city implementations. The ranking of the following human capital determinants would be a baseline for policy initiatives and investment decisions for smart city implementations. The description of the attributes is given in the following table.

Questions

Based on the scale given from 1-9, select the relative importance of the factor over the other by circling your choice. Please see the example below.

Example 1: Digital literacy is 'Much more important' than the Education.

Education	9	8	7	6	5	4	3	2	1	2	3	4	5	6	(7)	8	9	Digital literacy

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

Example 2: Education is 'Much more important' than the Digital literacy.

Education	9	8	(7)	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Digital literacy

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

Pair-wise Comparison (Level-1)

1- What is the more important component of human capital that contributes to the success of smart city implementation?

Qualification	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Personal Traits
Qualification	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Culture
Qualification	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social Factors
Personal Traits	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Culture
Personal Traits	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social Factors
Culture	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social Factors

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

Pair-wise Comparison (Level-2)

1- What is the more important component of qualification that contributes to the success of smart city implementation?

Education	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Digital Literacy
Education	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Experience
Digital Literacy	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Experience

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

2- What is the more important attribute of personal traits that contributes to the success of smart city implementation?

Intellectual Agility	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Behavior

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

3- What is the more important attribute of culture that contributes to the success of smart city implementation?

Lifelong learning	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	R&D Culture
Lifelong learning	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Entrepreneurial Culture
R&D Culture	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Entrepreneurial Culture

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

4- What is the more important attribute of social factors that contributes to the success of smart city implementation?

Life Expectancy	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Ethnic Plurality

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

Pair-wise Comparison (Level-3)

1- What is the more important attribute of education that contributes to the success of smart city implementation?

Level of Education	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multi-disciplinary scope of education

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

2- What is the more important component of digital literacy that contributes to the success of smart city implementation?

ICT User Skills	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ICT Specialist Skills

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

3- What is the more important component of experience that contributes to the success of smart city implementation?

Domain Specific Tacit Knowledge	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Learning by Doing

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

4- What is the more important attribute of intellectual agility that contributes to the success of smart city implementation?

Creativity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Imitation
Creativity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Adaptability
Imitation	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Adaptability

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

5- What is the more important attribute of Behavior that contributes to the success of smart city implementation?

Motivation	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Commitment
Motivation	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Teamwork
Motivation	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Leadership
Commitment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Teamwork
Commitment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Leadership
Teamwork	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Leadership

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

6- What is the more important attribute of lifelong learning that contributes to the success of smart city implementation?

Formal Learning	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Self-regulated learning

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

7- What is the more important attribute of R&D culture that contributes to the success of smart city implementation?

R&D Expenditure	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	R&D Personnel

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

8- What is the more important attribute of Entrepreneurial culture that contributes to the success of smart city implementation?

Enterprises density	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Enterprise birth density

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

9- What is the more important attribute of Ethnic Plurality that contributes to the success of smart city implementation?

International Students	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Skilled Immigrants

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

Section B:

This section requires your opinion in ranking the elements of the structural capital in terms of their importance towards the success of efficient and sustainable smart city implementations.

Structural Capital

Structural capital is the dimension of intellectual capital that covers the sources of value creation in 'process', 'infrastructure', and 'relational attributes'. Structural capital helps human capital create value. The components and indicators in the categories of process, relational and infrastructural dimension have been identified through the extensive literature on 24 smart cities case studies. The process component contains development method and management & control of smart city systems and the relevant policies. The relational dimension covers the engagement level of citizens in the smart city development process and the mode of communication amongst the participating agencies and organizations. Similarly, the infrastructure part lists down the valuable indicators and approaches in the use of information system, management of data and the state of the communication system.

Pair-wise Comparison (Level-1)

1- What is the more important dimension of structural capital that contributes to the success of smart city implementation?

Process	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Relational
Process	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Infrastructure
Infrastructure	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Relational

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

Pair-wise Comparison (Level-2)

1- What is the more important process component of structural capital that contributes to the success of smart city implementation?

Development Method	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Management & Control
Development Method	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Policy
Management & Control	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Policy

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

2- What is the more important relational component of structural capital that contributes to the success of smart city implementation?

Citizen Engagement	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Organizational Cohesion

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

3- What is the more important infrastructure component of structural capital that contributes to the success of smart city implementation?

Communication System	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Information Systems
Communication System	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Data Orchestration
Information Systems	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Data Orchestration

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

Pair-wise Comparison (Level-3)

1- What is the more important development method that contributes to the success of smart city implementation?

Top-down approach	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Bottom-up approach

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

2- What is the more important way of management & control that contributes to the success of smart city implementation?

Centralized	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Decentralized

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

3- What type of policy is more important as per the contribution towards the success of smart city implementation?

National Policy	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Local Policy

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

4- What is the more important mechanism for citizen engagement that contributes to the success of smart city implementation?

Engagement in development decisions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Post development Feedback

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

5- What is the more important attribute of organizational cohesion that contributes to the success of smart city implementation?

Horizontal communication	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Vertical communication

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

6- What is the more important attribute of communication system that contributes to the success of smart city implementation?

Fixed Broadband	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Mobile Broadband
Fixed Broadband	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Public Wi-Fi
Public Wi-Fi	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Mobile Broadband

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

7- What is the more important attribute of information system that contributes to the success of smart city implementation?

Development of New software Programs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Integration of Existing Programs

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

8- What is the more important attribute of data orchestration that contributes to the success of smart city implementation?

Central data bank	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Open Data
Central data bank	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Data Sharing Protocol
Open Data	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Data Sharing Protocol

1: Equal, 3: Slightly more Important, 5: More Important, 7: Much More Important, 9: Absolutely Important

Section C:

Demographic Information

(Please check (√) for the correct answer.)

1. Specify your gender?

☐Male ☐Female

2. Specify your age group?

☐18-25 ☐26-40 ☐41-60 ☐> 60

3. What is the highest level of education you have completed?

☐High school ☐Bachelor ☐Master ☐Doctorate

4. What is the nature of organization you are working for?

☐Academia ☐Private sector ☐Government ☐Self Employed

5. What is the name of your organizations, city and country?

_____

6. How much working experience do you have?

☐1~3 years ☐3~5 years ☐5~8 years ☐8~10 Years ☐More than 10 years.

Appendix C: Conjoint Survey for Citizen's Preference Analysis

This survey is intended to identify the willingness to adopt smart city services from Pakistani citizens. Please read the overview to get the understanding of the context of this survey.

Overview

Smart cities development uses integration of information and communication technologies (ICT) into city management functions like mobility, safety, crime prevention, waste management, disaster management etc. and government services etc. Citizens can use these services online either through web or mobile application. Few examples of these services are the access to traffic information, availability of parking slots in parking areas, waste pick up schedule, electronic payment of violation tickets, emergency alerts, and real-time metering information of utility services like electricity, gas. Similarly, processes of documents issuance like certificates (Family Registration etc), passports, citizenship cards applications and income and taxation related issues are made online through these services. Implementation and operations of these services can be owned by public sector, private sector or in a public private partnership mode. Interoperability between these services is the ability of information exchange between these services. For example, your payment of tax in telephone bill should automatically be represented in your FBR tax records.

This study is targeted to get your preferences towards different attributes of these services. These attributes can have different levels (or values) detail of which is given in the table below. Please go through the table to get the understanding of these levels before you move to next page.

In the question section, you have four choice sets; Choice set A, Choice set B, Choice set C, and Choice set D. Each Choice set contain four packages having different values of these attributes. Out of these four packages, you have to select one package, which is good enough for you to adopt smart city services. You have to repeat this for all four choice set while considering these choice sets independently.

Attribute	Level	Description
Language	Urdu	Urdu is used (along with English) as a language for the ICT applications being used by the end users.
	English	English is the only language used for the ICT applications used by the end users.
Access mode	Mobile app	The service is accessible to the users with a client side as a mobile application.
	Web	The service is accessible to users with client side through web and not as an installable mobile application.
Service Ownership	Public sector	Service is provided and operated by the public/Government sector organization
	Private sector	Service is provided and operated by the private sector organization
	Public Private Partnership	Service is provided and operated in public private partnership mode with the joint working of government and private sector.
Interoperability	Technical	Different applications are only able to exchange data. You can upload a file to government portal but someone has to interpret

		it. For example uploading your child birth certificate to update family record. This is minimum level of interoperability.
	Semantic	Application recognizes the data format and can interpret the data attributes and its meaning. for example the application can interpret the birth certificate and update record. This is medium level of interoperability.
	Organizational	Applications supports cross organization processes and features. Your tax deduction in telephone bills appear in FBR tax records. This is high level of interoperability.
Security	Basic	Confidentiality of the user's data and information including personal and financial information is ensured through minimum level of security.
	High	Basic level + security implemented to ensure the availability of services by protection through cyber-attack and other type of attacks which can degrade the service performance or make it unavailable.
Cost	500	Willing to pay minimum PKR 500 per annum for availing these services.
	1000	Willing to pay minimum PKR.1000 per annum for availing these services.
	1500	Willing to pay minimum PKR 1500 per annum for availing these services.
I Pakistani Rupee (PKR) = 0.0072 USD		

Choice Set A

	Package 1	**Package 2**	**Package 3**	**Package 4**
Language	Urdu	Urdu	English	Urdu
Access Mode	Web	Mobile App	Web	Mobile App
Service Ownership	Public Private Partnership	Public Sector	Public Sector	Private Sector
Interoperability	Technical	Technical	Technical	Organizational
Security	High	Basic	Basic	High
Cost	1000	500	500	500
Choice				

Choice Set B

	Package 1	Package 2	Package 3	Package 4
Language	English	Urdu	English	English
Access Mode	Mobile App	Web	Mobile App	Mobile App
Service Ownership	Public Sector	Private Sector	Public Private Partnership	Public Sector
Interoperability	Semantic	Technical	Technical	Organizational
Security	High	Basic	Basic	Basic
Cost	1000	1000	1500	1000
Choice				

Choice Set C

	Package 1	Package 2	Package 3	Package 4
Language	English	Urdu	Urdu	English
Access Mode	Web	Mobile App	Web	Web
Service Ownership	Private	Public Sector	Public Sector	Public Private Partnership
Interoperability	Semantic	Technical	Organizational	Organizational
Security	Basic	High	Basic	High
Cost	500	500	1500	500
Choice				

Choice Set D

	Package 1	Package 2	Package 3	Package 4
Language	English	English	Urdu	Urdu
Access Mode	Mobile App	Web	Mobile App	Web
Service Ownership	Private Sector	Public Sector	Public Private Partnership	Public Sector
Interoperability	Technical	Technical	Semantic	Semantic
Security	High	High	Basic	High
Cost	1500	500	500	1500
Choice				

국문초록

지식집약적 산업의 출현으로 기업, 지역 및 국가 차원에서 가치 창출의 숨겨진 출처를 파악하고 측정하는 도구로 사용되는 지적 자본 관리가 쟁점으로 떠올랐다. 지식집약적 기업은 순자산보다 훨씬 높은 평가를 받고 있기 때문에 그들의 학습과 자본화 시스템의 개선과 지속 가능성을 위해 회사의 무형 가치를 확인할 필요가 있다. 지적 자본 요소는 정보통신 기술을 이용해 도시 기능에 효율성과 지속성을 높이는 스마트 시티 개발에 활용될 수 있는 핵심 자원이다. 지적 자본 요소의 속성은 가치 창출과 생산성 및 성능 향상에 가변적인 영향을 미칠 수 있기 때문에 스마트 시티 구현에서의 지적 자본 요소의 역할을 연구할 필요가 있다.

지적 자본에 관한 중요한 연구 문헌들이 있지만 스마트 시티의 성공적인 구현을 위한각 요소들의 역할은 검토되지 않았다. 이 연구는 인적자본과 구조자본에 대한 전문가의 선호도 분석을 사용하여 스마트 시티의 성공을 위한 지적 자본 요소의 역할 조사를 목적으로 한다. 또한 수용 의사 결정에 영향을 미치는 스마트 시티 정보 서비스 특성에 대한 수요 측면의 관점도 조사한다. 분석은 인적 자본 및 구조적 자본을 위한 분석 계층 프로세스(AHP)와 스마트 시티 정보 서비스 채택을 위한 혼합 로짓 모델을 이용한 이산 선택 분석이라는 두 가지 방법을

사용한다.

첫 번째 연구는 다차원적 접근법을 사용해 개인 수준의 특성과 집단 행동을 이용한 인적 자본에 대한 모델을 개발한다. 인적 자본의 가치의 근원을 식별하는 것은 스마트 시티 구현 성공에 매우 중요하다. 이러한 능력들이 활용되고 개선되어 생산성과 성능을 향상시킬 수 있기 때문이다. 인적 자본 요소는 개인의 자격, 성격, 문화, 사회적 요인으로 분류되었다. 그 결과, 첫번째로 중요한 것은 개인의 자격요건이며 두번째는 문화임을 밝혀냈다. 또한, 전체적인 우선순위 가중치 추정은 경험을 통해 얻은 도메인 고유의 암묵적 지식의 존재, 다분야의 교육 범위 및 R&D 인력의 밀도는 스마트 시티 성공을 위한 인적 자본의 상위 3대 속성임을 보여준다.

구조적 자본에 관한 연구는 전 세계 24개 스마트 시티 사례를 조사해 스마트 시티 개발 과정에서 가치 있는 구조적 자본의 요소를 확인했다. 서로 다른 구조적 자본 요소의 조정은 개발 프로세스의 결과와 도시 시스템의 효율성에 영향을 미칠 수 있다. 확인된 구조적 자본 요소는 프로세스, 관계 및 기반 구조 차원으로 분류되었다. 이는 통신과 정보 시스템을 구성하는 기반 구조의 차원이 스마트 시티의 성공에 가장 중요하며 그 다음으로 정책의 가장 우세한 구성 요소를 가진 프로세스 범주가 중요하다는 것을 보여준다. 이들 요소의 전체 순위는 의

사결정자들이 혁신 생성을 위한 도시 수준의 정책과 절차 개발과 집행에 초점을 맞출 필요가 있음을 시사한다.

마지막으로, 스마트 시티 개발의 초기 단계에 있으며 수요 측면 관점에서 유용할 수 있는 파키스탄의 이슬라마바드 도시에 대한 시민의 선호 분석이 이루어졌다. 본 연구에서 고려한 스마트 시티 정보 서비스의 특성은 언어, 접근 모드, 서비스 소유권, 상호운용성 및 보안으로 구성된다. 지불 의지는 최종 사용자의 선택에 따른 가격 민감도를 관찰하기 위해 사용되었다. 연구 결과는 이슬라마바드 시민들이 높은 수준의 보안과 함께 영어 사용에 더 높은 효용을 가지고 있다는 것을 보여준다.

결론적으로, 이 연구는 특별히 스마트 시티 개발의 초기 단계에 있는 정책 입안자들을 위한 지침을 제공한다. 이슬라마바드시에 대한 수요 측면 연구는 스마트 시티 서비스의 신속한 채택을 지원하는 기존 추세에 대한 귀중한 통찰력을 제공한다.

주요 단어: 스마트 시티, 지적 자본, 인적 자본, 구조적 자본, 정보 서비스

Acknowledgments

I would like to express my warmest gratitude to my beloved parents, my father Muhammad Murtaza Khan and my mother Aqeela Parveen, for their unconditional love, encouragement, and continuous support over the years of my life. I am very thankful to my beloved wife for her support during tough times of my study in Korea. I dedicate this dissertation to my dearest family, particularly my father, my mother, my wife and daughter, my brother and sweet sisters, and all members of my great family.

I would also like to express my sincere gratitude and deep appreciation to my academic advisor, Professor Junseok Hwang, for his valuable academic support and excellent guidance during my PhD study and research, for his patience, motivation and knowledge. Without his motivation, enthusiasm, constant guidance, and encouragement, I would not have been able to complete my dissertation. His guidance helped me in all the times of research and writing of this thesis. I could not have imagined having a better advisor and mentor for my PhD study. I am highly thankful to him for being a great source of inspiration and making me a better person.

I would like to express my sincere and genuine thanks to Professor Hyenyoung Yoon for her support, valuable discussions, and beneficial comments during my research work. She has been very kind, generous, and helpful during my entire journey at Seoul National University. Without her sincere and great support, I would not have overcome the challenges of completing my research.

My sincere thanks and appreciation also go to Professor Jorn Altmann, the chair of my dissertation committee, for his beneficial comments and valuable guidance and discussions during numerous lectures and seminars over the academic semesters.

Furthermore, I would like to extend my thanks and appreciation to my dissertation committee members, Professor Hoon Han and Professor Daeho Lee, for their excellent comments and suggestions that helped to improve this dissertation.

Additionally, I extend my gratitude to my research team members for their feedback during the team meetings. In particular, I am grateful to Eunha Kim for her support during the research phase of my PhD study.

A very special gratitude goes to all the staff of ITPP, IEPP, and TEMEP for their kind support, patience, and care during my three years in this beloved country Korea. I am highly obliged to Miss. Mihee Kim and Miss. Kwiyeong Kwon for their support during the study period.

Last but not the least; I would like to thank the Ministry of Science and ICT in Korea for providing me this opportunity to pursue my PhD study in one of the best universities in the world.

Muhammad Tanzeel Murtaza Khan

February, 2019