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Graduate School of Management

Master in Information Technologies and Innovation Management

PERFORMANCE MANAGEMENT & MEASUREMENT MODEL FOR SMART CITIES

Master's Thesis by the 2nd year student
Concentration – MITIM
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ЗАЯВЛЕНИЕ О САМОСТОЯТЕЛЬНОМ ХАРАКТЕРЕ ВЫПОЛНЕНИЯ ВЫПУСКНОЙ КВАЛИФИКАЦИОННОЙ РАБОТЫ

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АННОТАЦИЯ

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Описание целей, задач и основных результатов исследования	Целью исследования является создание модели (целостного подхода), включающей в себя набор качественных и количественных показателей, которые могут быть использованы для оценки эффективности функционирования интеллектуальных городов. Задачи текущей магистерской диссертации включают в себя детальный обзор литературы на тему «Умный город» для определения основных понятий; проведение интервью с представителями умных городов; создание концептуальной модели управления эффективностью умных городов, основанной на экспертных интервью; проведение массового анкетного опроса с целью проверки концептуальной модели и окончательной доработки результатов при помощи модели управления и измерения эффективности умных городов. На основании данных, собранных в ходе интервью с представителями интеллектуальных городов, а также опроса представителей IT компаний и университетов, была представлена пятиуровневая модель управления эффективностью деятельности умных городов. Основная ценность представленной модели заключается в сопоставлении целей умного города с конкретными качественными и количественными ключевыми показателями эффективности. Представленная модель управления и измерения эффективности деятельности умных городов может быть использована на практике администрацией рассмотренных умных городов, а также представителями бизнеса, частными лицами и представителями администрации других умных городов.
Ключевые слова	Умный город, оценка эффективности, ключевые показатели эффективности (КПЭ), модель управления, оценка эффективности, информационно-коммуникационные технологии (ИКТ)

ABSTRACT

Master Student's Name	Svetlana Kuznetsova
Master Thesis Title	Performance Management and Measurement Model for Smart Cities
Faculty	Graduate School of Management, Saint Petersburg University
Program	38.04.02 «Management»
Year	2016
Academic Advisor's Name	Dr. Tatjana Samsonowa, Associate Professor
Description of the goal, tasks and main results	The goal of the current research is to create the model (holistic approach) with both qualitative and quantitative indicators that can be used for assessing performance of smart cities. The objectives of the current master thesis include in-depth literature review on "smart city" concept definitions; conducting expert interviews with the representatives of smart cities; creating the conceptual model for performance management of smart cities based on expert interviews; making mass survey in order to check the conceptual model and finalizing results through the performance management and measurement model for smart cities. Based on the data collected with expert interviews and survey a five-level performance management model for smart cities is suggested. The key value of the model provided is mapping goals of smart city with concrete qualitative and quantitative KPIs that can be used to assess the performance of the smart urban settlement. The constructed performance management and measurement model can be used in practice by both internal (smart city managers) and external stakeholders (business, individuals and city managers of other smart cities).
Keywords	Smart city, performance measurement, key performance indicators (KPI), performance management and measurement model, Information and Communication Technologies (ICT)

TABLE OF CONTENTS

INTRODUCTION

One of the most popular and trendy words nowadays is the word “smart” that is understood by people all over the world as “intelligent”, “innovative”, and “high-tech”.

In the XXI century things around us are becoming smarter and our life is getting more comfortable, safe and exciting due to the rapid development of Information and Communication Technologies (ICT), digitalization of services and the deep integration of smart devices and gadgets (such as smartphones, ultrabooks, tablet computers, etc.) into our daily life.

The development of smart technologies is quite rash. Just several years ago specific smart devices were considered as something extraordinary, however today the development of whole smart cities is already observed. Smart city development started from “smart houses” (Park et al., 2003; Ricquebourg et al., 2006) and nowadays continues as evolution of “smart cities” in which people will be relieved from widely spread problems such as traffic jams, queues, dependence on energy, etc. (Hollands, 2008; Nam and Pardo, 2011; Chourabi et al., 2012).

At present smart technologies are actively used for private and business purposes in various industries but in several years such technologies will become a crucial part of all the spheres of our life dramatically changing the direction of social development and turning us into the smart society.

Despite the fact that there is a great amount of research on smart city concepts and also a large number of practical examples of modern and innovative cities of new generation, the question of analyzing performance and measuring effectiveness of these “smart cities” is still open.

The goal of current master thesis is to create the model (holistic approach) with both qualitative and quantitative indicators that can be used for assessing performance of smart cities.

Research questions to be answered within the current master thesis were formulated as the following ones:

- What is the common practice in regard to performance management of smart cities? Are there common smart city goals, and are there common key performance indicators (KPIs) to assess performance?
- Is there a generic performance management approach to describe the common practice of performance management of smart cities? How are goals and KPIs reflected in this approach?
- Can the holistic performance management model be provided based on the practices of real smart cities?

- Can there any recommendation be derived from the suggested approach to advise on the implementation and further development of a performance management and measurement model in smart city?

To achieve the research goal, the master thesis will address the following *objectives:*

- conducting in-depth literature review on "smart city" concepts and definitions;
- conducting interviews with experts in planning and construction of smart cities;
- creating the conceptual model for performance measurement of smart cities based on expert interviews;
- making mass questionnaires to validate the conceptual model;
- finalizing results through the performance measurement model for smart cities.

The first chapter of the master thesis presents the state-of-the-art in the smart city concept and reviews the theoretical background of the topic, "smart city" definitions, approaches to smart city initiatives, examples of smart cities in the Russian Federation and all over the world. Moreover, the importance of the performance management and measurement model for "smart cities" is justified.

The second chapter describes the methodological framework of research which results are presented in the third chapter. The main tools to be applied in this research include in-depth interviews with experts from the current scientific, questionnaires that allow collecting the feedback and statistical results to create the base for the performance management and measurement model for smart cities. Furthermore, the five-level performance management model (Samsonowa, 2012) created for R&D departments is adapted for measuring the performance of smart cities.

The third chapter gives the overview of key findings of research and final results achieved. Results from expert interviews present a basis for building the preliminary performance management and measurement model. All the data collected from expert interviews and survey is analyzed and used to build the final performance management and measurement model. Information gained from expert interviews with smart cities representatives are presented in the form of case studies for each smart city. Moreover, the final model maps goals of smart cities with KPIs classes and specific qualitative and quantitative ratios to assess the smart city performance.

Finally, conclusions and practical recommendations are given based on the final performance management and measurement model for smart cities. Moreover, the model presented can be adapted to various smart cities depending on their goals, principles, economic, cultural and political peculiarities. Current master thesis brings both theoretical and practical

value since it contains not just the in-depth literature analysis of the smart city concept, but also describes specific KPIs that can be used by smart city initiatives to assess their performance.

1. STATE-OF-THE-ART IN "SMART CITY" CONCEPT

The current chapter will present the state-of-the-art in smart city concept. It will provide in-depth analysis of smart city phenomenon with comparison of the range of smart city definitions while presenting common components of various viewpoints. Furthermore, the set of practical examples of implementation and realization of smart city strategy will be presented. Such practical experiences provided will include both world and Russian smart cities. Moreover, the literature analysis of performance management and performance measurement concepts will be also suggested for better understanding of the final Master thesis outcomes.

1.1. Theoretical background of "smart city" concept

Nowadays the level of migration is continuously increasing all over the world. According to United Nations (2014), by 2050 more than 60% of population will be living in small towns, cities or megalopolises. This clearly defined tendency of the growing urbanization and increasing complexity of the daily life in cities make government develop new strategies on urban development and take care of citizens' comfort.

To fight challenges many large cities face today such as traffic congestion, pollution, depletion of natural resources, increased workload on the existing infrastructure, etc., city managers are trying to adopt technology-based approaches that cause the concept of smart city to appear.

In spite of the fact that there are already several examples of smart city projects being implemented, there is still no universal definition of the smart city. To identify the common features of smart cities outlined by scholars and researchers, several sources with specific interpretations of the smart city concept were compared (Table 1).

In many articles that cover the current topic (Hall, 2000; Cosgrave et al., 2013), smart city is considered as the urban center of the future that is efficient, environmentally friendly and safe. It means that all the structures inside such a city are designed and constructed with use of integrated, advanced materials of high-quality, electronic sensor devices, and overall computerized systems that combine databases and decision-making algorithms. This definition illustrates that smart city touches all parts of urban life such as healthcare, education, infrastructure (buildings, tunnels, bridges, seaports, railway stations, airports, roads), transport and logistics, energy, environment, etc. Also, as the smart city concept is closely related to sustainable development three important aspects must be considered. Firstly, needs of the population are fulfilled through increasing the life quality; secondly, the impact on environment

must not exceed established norms (effective and reasonable use of natural resources is crucial); and, finally, the population must not endanger the life of future generations.

The European Commission states that a smart city is a place where traditional services and networks provided for citizens can be characterized as highly qualified and more efficient through the use of telecommunication and digital technologies "for the benefit of its inhabitants and business". The example of smart city projects carried out by the European Commission is the European Innovation Partnership on Smart Cities and Communities (EIP) initiated in July, 2012 to accelerate the development of "smart cities" all over the world. This EIP is going to implement smart technologies into such areas as urban transport networks, water supply, waste of disposal facilities, lighting and heating of buildings. It also comprises a more responsive and interactive city administration for meeting the ageing population's needs and creating safer public spaces (Digital Single Market, 2016).

British Standard Institute defines smart city as quite effective integration of such systems as physical, human and digital in the built environment in order to deliver inclusive, prosperous and sustainable future of its citizens (Gktoday.in, 2016).

IBM emphasizes that all types of smart cities are based on new innovative technologies and insights with the aim of transforming their systems, operations and service delivery. Furthermore, the concept of "smart city" is closely connected with high competition among cities for new residents, visitors, investors and businesses what leads to providing the vibrant economic climate and the high quality of life. IBM even puts the emphasis on three dimensions: planning and management, infrastructure and people. Planning and management makes the accent on efficient daily management that helps city stay safe and vital for its citizens and businesses. Infrastructure includes key fundamental services such as roads, bridges, utilities and mass transit systems that keep city livable and desirable. As for the people, all innovations and smart services support the needs of citizens through social programs, healthcare, education, etc. (Smarter Planet, 2016).

Cisco describes smart cities along with additional term that is smart and connected communities (S+CC). All in all, Cisco believes that serious problems such as increased population, polarized economic growth, increased greenhouse-gas emissions, decreased budgets and others can be solved with scalable solutions that take advantage of Information and Communication Technologies (ICT) in order to reduce costs, increase efficiency, and enhance the quality of life. Moreover, from the Cisco point of view, the main barrier to implementing such kind of solutions is the complexity of how cities are financed, regulated, planned and operated. On the other side, smart cities present the great opportunity to integrate various

physical infrastructures: transportation systems, utilities, real estate, city services, etc. (Falconer and Mitchell, 2012).

Although smart city definitions are numerous, it is possible to outline some common features attributed to smart cities by scholars and researchers. In general, smart city provides an intelligent way of managing its structures and systems such as energy, transport, healthcare, buildings, homes and also the environment. It means that "smart city" generally operates in the complex urban environment, causing the collaboration between complex technological systems, city infrastructure, human behavior, economy, political and social structures (Gaur et al., 2015).

Table 1

Definitions of "smart city"

Source	**Definition**
Hall (2000)	"The urban center of the future, made safe, secure environmentally green, and efficient because all structures - whether for power, water, transportation, etc. are designed, constructed, and maintained making use of advanced, integrated materials, sensors, electronics, and networks which are interfaced with computerized systems comprised of databases, tracking, and decision-making algorithms".
Washburn and Sindhu (2009)	"The use of ICT [makes] the critical infrastructure components and services of a city – which include city administration, education, healthcare, public safety, real estate, transportation, and utilities, more intelligent, interconnected, and efficient".
Caragliu et al. (2011)	"A city is 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".
Angelidou (2014)	"All urban settlements that make a conscious effort to capitalize on the new Information and Communications Technology (ICT) landscape in a strategic way, seeking to achieve prosperity, effectiveness and competitiveness on multiple socio-economic levels".
Perbolia et al. (2014)	"Smart City proposes a holistic vision of future communities where new intelligent technological tools, services and applications are integrated in a unique platform, providing interoperability and coordination between such sectors as building, energy, environment, government, living, mobility, education, health".
Cisco Systems, Inc. (2014)	"An integrated urban information and communication technology (ICT) overlay on a city that can support delivery of connected urban services and allow for efficient management of those services on a global scale".
The British Standards Institution (2014)	"Effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens".
The European Commission (2014)	"A city seeking to address public issues via ICT-based solutions on the basis of multi-stakeholder, municipally based partnership".

The Smart Cities Council (2015)	City that "uses information and communications technology (ICT) to enhance its livability, workability and sustainability".

Table 1 (continuation)

IBM Corporation (2016)	"Smarter cities of all sizes are capitalizing on new technologies and insights to transform their systems, operations and service delivery (water, transportation, energy) and improve citizens' life through social programs, healthcare, and education".

Some of these definitions are more focused on specific aspects such as technologies, data or citizens while others have a broader focus. In order to formulate the definition of smart city to be used for the current research, all definitions above were compared and the most popular and common features were identified (Table 2).

Table 2

Comparison of "smart city" definitions

Source	**Composite elements mentioned in "smart city" definitions**				
	Sustainable development	The use of ICT	High quality of citizens' life	Effective government management	Green & Eco environment
Hall (2000)		∨	∨	(∨)	∨
Caragliu et al. (2009)	∨	∨	∨	∨	∨
Washburn and Sindhu (2009)		∨	∨	∨	
Angelidou M. (2014)	(∨)	∨	∨	∨	
Perboli et al. (2014)		∨	∨	∨	∨
Cisco Systems, Inc. (2014)		∨	∨	∨	∨
The British Standards Institution (2014)	∨	∨	∨		
The European Commission (2014)	∨	∨	∨	∨	∨
The Smart Cities Council (2015)	∨	∨			
IBM Corporation (2016)		∨	∨	∨	

* ∨ component is explicitly mentioned in the definition
(∨) component is not explicitly mentioned, but is implied in the definition

All in all, smart city can be identified as an urban settlement that provides the high-quality life for its citizens (in spheres such as transportation, healthcare, education, public safety, etc.) through effective government management and the efficient use of Information and Communication Technologies (ICT).

To summarize all the points discussed above and make the current topic more clear all the information on the "smart city" concept was combined in the mind map (Figure 1). This mind map shows that smart technologies can be implemented in various areas of citizens' life, facilities and institutions such as hospitals, public transport systems (metro, buses, trams, etc.), schools, universities, roads, buildings, shopping centers and many others. Implementation of technologies and innovations allow eliminating problems the increasing population face today and making the daily life of people more comfortable and safe along with the rising level of urbanization. Tools such as available computer centers, applications for smartphones and tablets, electronic sensor devices in the city streets and the single operational control center are great means to achieve goals that are set to make the city smart.

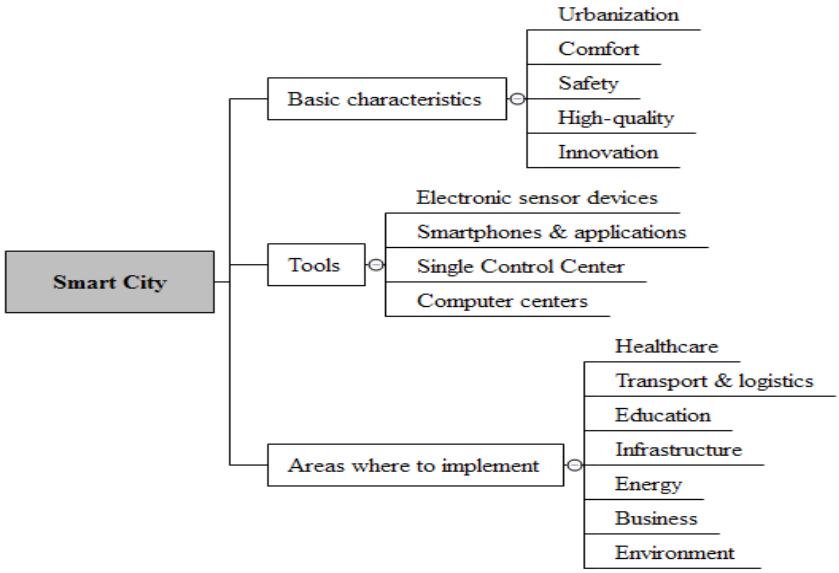

Figure 1 Mind map of smart city

Concerning smart city initiatives, they differ from each other depending on economic, political, and cultural peculiarities of the country. In particular, approaches to smart city initiatives can be divided into two different groups. The first group is presented with "top-down" approaches that focus on various technologies, master planning, efficiency, integrating data and information from different systems into a single operational center. "Bottom-up" approaches focus on citizens and the means of how the local population use mobile applications, social media, computer centers, sensor devices, etc. (all the types of innovative modern technologies) in order to solve daily problems through creating absolutely new solutions able to change the situation in the city (Nam and Pardo, 2011; Komninos et al., 2012; Kitchin, 2014).

It is very important to mention while making the link between theory and practice in the smart city concept that with a view to assist in creating cities of the future the Smart Cities Council was formed. The Smart Cities Council is the industry coalition formed in order to accelerate the movement to smart and sustainable cities. The Council states that the smart city is

one that has digital technologies crossing all functions and systems in this city (Smartcitiescouncil.com, 2016). The vision of the Smart Cities Council is closely connected with the definition above: the participants and members envision the world where the intelligent design and digital technologies are combined to create sustainable smart cities with high-quality living and high-quality jobs. Consequently, three core values of such new cities are outlined:

- Livability (cities without pollution and congestion, with clean and healthy living conditions),
- Workability (cities providing infrastructure for completing globally high-quality jobs)
- Sustainability (cities providing various services without stealing from next generations) (Smartcitiescouncil.com, 2016).

While to create intelligent modern cities the Smart Cities Council also closely collaborates with key business partners such as Cisco, General Electric, IBM, Microsoft, MasterCard and many others.

1.2. Smart cities in practice

The beginning of XXI century became the incremental step in development of the smart city concept with the implementation of projects on intelligent cities in practice. The decision of how the process of continuous smart city functioning is organized refers to the cities themselves. Such organizational decisions are under control of the city administration or even single separate initiatives. Based on the real examples of smart cities, they can be divided into two types. (Figure 2).

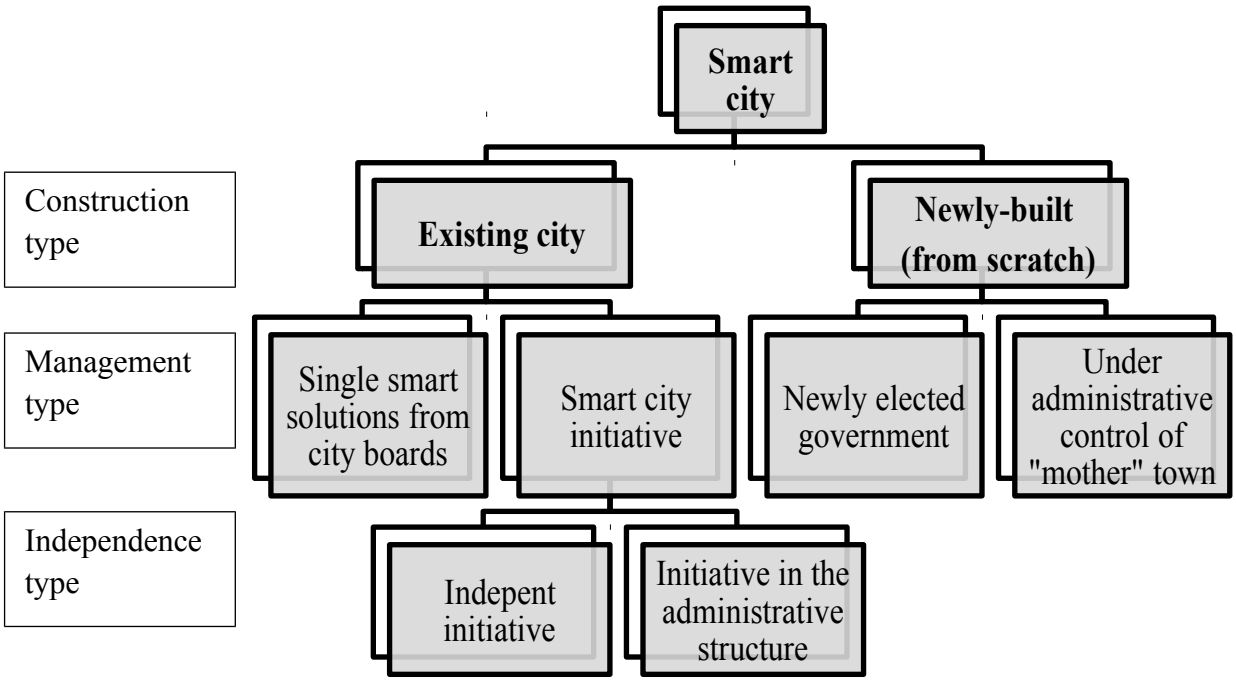

Figure 2 Smart city types

The first group of intelligent settlements includes cities that already exist through developing and implementing smart strategies that can be assigned with the status of smart city. Nowadays, several European cities are the perfect illustration of these intelligent cities.

The European Parliament that took smart city development in Europe under control aims to develop the single smart city concept for the European Union and outline characteristics or components of the intelligent city. It was already mentioned previously that the European Parliament draws the great attention to ICT-based solutions while defining smart city. It assumes that smart city has characteristics such as Smart Governance, Smart People, Smart Living, Smart Mobility, Smart Economy and Smart Environment.

Based on the smart city definition and six key characteristics of smart cities the European Parliament supposes that the status of smart city can be assigned to those having at least one key characteristic announced by the European Parliament. It means that by 2011 240 out of 468 EU cities (51% of the total number) had one or more smart city characteristics and were classified as smart cities.

The distribution of intelligent settlements is consistent for the whole Europe. The countries with the highest absolute number of smart cities include the United Kingdom, Spain and Italy, while the countries that have the highest proportion of smart cities in Europe are Italy, Austria, Denmark, Norway, Sweden, Estonia, and Slovenia (European Parliament, 2014).

In 2014 the European Parliament announced the six most successful European cities with smart city initiatives. This set of cities is based on the fact how cities perform in the context of their country's national priorities alongside with socio-economical and political circumstances and the alignment of each city to the European strategy and targets for future development. This list includes Amsterdam (the Netherlands), Barcelona (Spain), Copenhagen (Denmark), Helsinki (Finland), Manchester (the United Kingdom), and Vienna (Austria) (European Parliament, 2014).

Actually, each smart city can be independent in smart solutions and projects that it implements to enhance the performance of all city areas. For example, Amsterdam provides a great amount of projects in city domains such as smart mobility, smart society, smart living, smart economy, and infrastructure (Amsterdam Smart City, 2016). Barcelona Smart City initiative puts efforts on finding solutions in the city areas of public and social services, environment, mobility, companies and businesses, research and innovation, communication infrastructure, tourism, and citizen cooperation (Smartcity.bcn.cat, 2016).

The second group of intelligent cities includes those smart cities that are built from the scratch as totally new projects for creating better living circumstances for its future citizens and also positioned as cities of the completely new generation. By now there are only several

practical examples of these cities as planning and construction processes take the long period to be realized.

Songdo International Business District (IBD) is a new smart city that is built from the scratch and that occupies the territory of approximately 6 km^2 on the northeast of South Korea. The story of Songdo starts in 2001 when Incheon Metropolitan City[1] invites Gale International, the privately owned real estate development company based in New York to tour the project site. On the fourth year the master plan of the future smart city was completed and signed. The very first construction works were finished in 2009 with the opening of the Central Park, the first residential and commercial project. During ten years Songdo was successful in constructing and providing its residents with four international university campuses, schools, wide roads, higher number of bicycle paths and walkways, the 65-floor Northeast Asia Trade Tower and green spaces amounting to 40% of the whole city area.

Actually, Songdo IBD is an urban settlement designed for the people who work and live there. This city aims to combine the ideal mix of residential, business, retail, cultural and recreational environments. Nowadays, there are over 1,000 retail and hospitality businesses operating, over 1,600 global and domestic companies located in Songdo. Moreover, as this smart city is not just for businesses but also for the better life of its citizens, there are over 20,000 residential units occupied and 36,000 residents living in this South Korean intelligent settlement (Songdoibd.com, 2016).

Masdar City is a planned city project in Abu Dhabi, the United Arab Emirates (UAE). The construction works were under control of Masdar, a renewable energy company also based in the UAE, while major capital investments referred to the Government of Abu Dhabi. The city master plan was signed in 2008 and the same year construction works started. Actually, the city is designed to become a hub for cleantech companies that specialize in recycling, IT, green transportation, green chemistry, and electric motors. Nowadays, there are several thousand residents living and also working on the territory of this city. Moreover, Masdar City still continues to add new schools, universities, businesses, restaurants, accommodation and much more while creating the diversity of modern city with the plan to provide facilities for 40,000 citizens in the nearest future (Masdar.ae, 2014).

As for the Russian experience in smart city development, smart city initiatives mainly relate to projecting and constructing of new urban settlements from the very scratch. There are several smart city projects in the Russian Federation mainly on the construction stage.

In particular, there are already two initiatives of intelligent cities from the Agency of Investment Development of the Republic of Tatarstan such as Smart City Kazan and Innopolis

1 The Incheon Metropolitan City is a city located on the northwest of South Korea

(Tida.tatarstan.ru, 2016). Moreover, Skolkovo City is also the new urban settlement located in Moscow on the territory of the Skolkovo Innovation Center.

Smart City Kazan is the holistic urban planning according with the smart city concept alongside with the project of green city development that was presented in 2012. At present, the construction works are still in progress with the aim of developing four key city areas that are the central business precinct, the knowledge and education precinct, the special economic zone, the enterprise precinct, and Parkland. The overall population is predicted to be about 58,800 citizens. Moreover, the approximate number of jobs created will amount to 39,000; a number of residential units will reach 16,620; and total building gross floor area (GFA) is predicted to be 7 mln m^2 (Kazansmartcity.com, 2016). Overall, Kazan Smart City will be designed and constructed based on five key principles including eco-urbanism, smart growth, smart location, low carbon, inclusive and identity (Kazansmartcity.com, 2016).

Innopolis is also a newly built city located on the territory of the Republic of Tatarstan. The city economy is based on the high-tech industries. A unique safe environment alongside with the modern residential infrastructure, broad opportunities for education and professional development have been created in Innopolis. In June, 2012 the Prime Minister of the Russian Federation together with the President of the Republic of Tatarstan signed the agreement for the construction of the new intelligent city. The master plan of Innopolis was proposed by architects from Singapore. The foundation ceremony took place in 2015. Nowadays, the city provides multifamily houses and townhouses for 5,000 people, schools, kindergarten designed for 225 children, the special economic zone for business representatives, the Innopolis University focusing on information technologies. In the following years the existing infrastructure will be expanded (Innopolis.ru, 2016).

Another smart city in the Russian Federation named “Skolkovo” is located close to Moscow. The very first objects appeared on the territory of the innovation center already in 2012, however, the major part of the construction works are planned to be finished in 2017. In this center of innovations constructors expect to provide optimal opportunities for research organizations and businesses and also to create the attractive city environment that will be comfortable both for residents and guests. The key elements of Skolkovo will be the University and the TechnoPark besides the Congress center, numerous office and laboratory buildings, sport centers and shopping malls. Additional attention is also paid to parks and other public places where citizens will spend their free time. For the convenience, local jobs will be created near housing estates so that employees will economize on the commuting time. Skolkovo search for options to implement on its territory all modern solutions aimed to improve the overall urban environment (Skolkovo Community, 2016).

Despite the fact that there are several practical examples of smart cities and smart city strategies being implemented, the phenomenon of smart city is relatively new. That explains the lack of instruments, systems and models to be used for evaluating the performance of smart cities. In order to better outline the research gap for the current research, the literature review of the performance management concept was also conducted.

1.3. Performance management and measurement background

Since the goal of the current research is to create the model that can be used to measure the performance of smart cities, alongside with the definition of smart city the terms of performance management and performance measurement were identified.

For the better understanding of the state-of-the-art in performance management the literature review was conducted (Table 3). Mainly, performance management is regarded as a continuous process with several step swith various types of actions such as performance planning, performance monitoring, and performance assessment (Brudan, 2010; Suhardi, 2015).

In spite of the fact that the performance management process can be different to some extent in various companies and departments, its overall goal is generally the same. Performance management aims to initiate positive changes in the organizational process and results (Amaratunga and Baldry, 2002; Tantardini and Kroll, 2015). While in some cases performance management leads to changes in the strategy and the review of organizational goals (Striteska, 2012; Waal, 2013).

Table 3

Definitions of "performance management"

Source	Definition
Amaratunga and Baldry (2002)	"The use of performance measurement information to effect positive change in organizational culture, systems and processes, by helping to set agreed-upon performance goals, allocating and prioritizing resources, informing managers to either confirm or change current policy or programme directions to meet those goals, and sharing results of performance in pursuing those goals".
Krause (2005)	"Performance management encompasses all activities that are aimed at the optimization of stakeholder benefits through the constant improvement of the players' professional competence and social skills, and at the same time, that minimize the financial, physical, temporal, emotional and social effort".
Brudan (2010)	"Performance management is the overarching process that deals with performance. It reflects the approach one entity has towards performance and it includes sub processes such as: strategy definition (planning/goal setting), strategy execution, training and performance measurement".
Osmani and Maliqi (2012)	"Performance Management identifies the organization's

	objectives, the necessary results to achieve these objectives, the ways to be effective these objectives, and the drivers to achieve them".
Striteska (2012)	"Performance management is a strategic approach to management which provides managers, employees and stakeholders at different levels with instruments necessary in order to regularly plan, continuously monitor, periodically measure and review performance of an organization".
Waal (2013)	"Performance management is defined as the process in which steering of the organization takes place through systematic definition of mission, strategy, and objectives of the organization, making these measurable through critical success factors and key performance indicators in order to be able to take corrective and preventive actions to keep the organization on track to great performance".
Ammons (2015)	"Performance management actions begin with observing the current state of performance, proceed to committing to the pursuit of a more favorable level of performance, and culminate in taking steps to achieve the targeted level".
Striteska and Jelinkova (2015)	"Defining a strategy that expresses what the company wants to achieve in the future and through which activities", while "monitoring and measuring plays a key role".
Suhardi (2015)	"Performance management is a series of activities starting from performance planning, monitoring/review of performance, performance assessment and follow-up in the form of rewards and punishment".

Through the comparison of various definitions of performance management, the composite components included in these definitions were identified (Table 4). The analysis of performance management definitions allowed identifying that in most cases this process has setting goals as the first step. It assumes the short-term or long-term planning of future actions and results to be achieved. In order to assess the performance, specific ratios and key performance indicators (KPIs) are used based on the goals previously set and the data collected (Waal, 2013; Tantardini and Kroll, 2015). Continuous monitoring and analysis is necessary to summarize KPIs' values and use them more efficiently to take further decisions. Finding the ways and methods to improve effectiveness and efficiency of the company's actions and programs is both the final step of performance management and also its key objective (Osmani and Maliqi, 2012; Waal, 2013). Finally, the decisions about punishment in case of low organizational performance or rewards in case of high organizational performance can be made (Suhardi, 2015).

Table 4

Comparison of "performance management" definitions

Source	**Composite elements mentioned in "performance management" definitions**			
	Planning/ goals	Performance	Monitoring/	Performance

	setting	measurement	Analysis	review/ Finding ways to improve performance
Amaratunga and Baldry (2002)	∨	∨		∨
Krause (2005)		(∨)	∨	∨
Brudan (2010)	∨	∨	(∨)	∨
Osmani and Maliqi (2012)	∨	∨	(∨)	∨
Striteska (2012)	∨	∨	∨	∨
Waal (2013)	∨	∨	(∨)	∨
Ammons (2015)		∨	∨	∨
Striteska and Jelinkova (2015)		∨	∨	∨
Suhardi (2015)	∨	∨	∨	(∨)
Tantardini and Kroll (2015)		∨		∨

* ∨ component is explicitly mentioned in the definition
(∨) component is not explicitly mentioned, but is implied in the definition

Based on the literature review presented above it is assumed that performance management is a process that includes such activities as goals setting, periodical measurement of performance through various KPIs alongside with their continuous analysis, and taking further decisions to improve effectiveness and efficiency.

It should be emphasized that performance measurement is considered as a substantial part of performance management (Striteska, 2012; Suhardi, 2015). Analysis of various literature sources (Table 5) gives better understanding of basic and additional features of performance measurement and shows that performance measurement is the process and one of the fundamental organizational functions that allows assessing the performance of company, department or even the individual person (Aracioglu et al., 2013; Zamecnik and Rajnoha, 2015). Performance measurement as a tool to measure effectiveness and efficiency (Neely et al., 1995; Rezaei et al., 2011) generally consists of such steps as data collection, calculation of key performance indicators (KPIs) to assess the performance, and final reference to analysis of ratios evaluated (Nappi and Rozenfeld, 2015).

Moreover, performance measurement and reporting as substantial organizational function can be realized through two levels (Atkinson et al., 1997; Kerssens-Van Drongelen and Fisscher, 2003). The first level is connected with a company as a whole that presents results of current position and its performance to external stakeholders. While the second level takes place inside

the company between its managers and subordinates. However, at both levels it can be three different types of actors who are evaluators (external stakeholders or company's managers), "evaluatees" (company as whole or middle managers), and assessors (external auditors or internal controllers).

Table 5

Definitions of "performance measurement"

Source	**Definition**
Neely et al. (1995)	"Performance measurement can be defined as the process of quantifying the efficiency and effectiveness of action; the process of quantifying action, where measurement is the process of quantification and action correlates with performance".
Atkinson et al. (1997)	"Our approach to performance measurement focuses on one output of strategic planning: senior management's choice of the nature and scope of the contracts that it negotiates, both explicitly and implicitly, with its stakeholders. The performance measurement system is the tool the company uses to monitor those contractual relationships".
Kerssens-Van Drongelen and Fisscher (2003)	"Performance measurement and reporting takes place at 2 levels: (1) company as a whole, reporting to external stakeholders, (2) within the company, between managers and their subordinates. At both levels there are 3 types of actors: (a) evaluators (e.g. managers, external stakeholders), (b) "evaluatees" (e.g. middle managers, company), (c) assessor, which is the person or institution assessing the effectiveness and efficiency of performance measurement and reporting process and its outputs (e.g. controllers, external accountant audits)".
Moullin (2007)	"Evaluating how well organizations are managed and the value they deliver for customers and other stakeholders".

Table 2 (continuation)

Rezaei et al. (2011)	"A set of metrics used to quantify both the efficiency and effectiveness of actions. Performance measurement methods are attractive to researchers. Performance measurement helps to bring more scientific analysis into a decision-making process. It underlines the change towards management by information and knowledge, instead of primarily relying on experiences and judgment".
Aracioglu et al. (2013)	"Performance measurement is one of the fundamental management functions. Evaluating performance, reviewing changes in the surrounding environment and making adjustments are normal and necessary parts of the strategic management process".
Ivanov and Avasilcai (2014)	"The main role of performance measurement is to assess the current position of the organization and also to help managers create and implement a better strategy".
Balabonienė and Večerskienė (2015)	"The performance measurement is the tool that describes the organization's improvement because it is not possible to any organization to act effectively without having its performance measured".
Nappi and Rozenfeld (2015)	"Performance measurement is the process of quantifying efficiency and effectiveness of actions. To this end, performance indicators

	should be chosen, implemented, and monitored. Performance indicators are the metric used to quantify the efficiency and/or effectiveness of actions of part or of an entire process or a system in relation to a pattern or target. These performance indicators are essential elements for planning and strategic control cycles”
Zamecnik and Rajnoha (2015)	“The term “Performance Measurement (Business Performance Measurement, Corporate Performance Measurement or Enterprise Performance Measurement)” means the creation and use of usually several indicators of various dimensions (e.g., cost, time, quality, innovation capacity, customer satisfaction), which are used to assess effectiveness and efficiency of the performance and performance potentials of different objects in the enterprise, the so-called levels of performance (e.g., organizational units of various sizes, staff, processes)”.

Based on the literature review of performance measurement the range of composite elements is presented below (Table 6), starting from the key goal of performance measurement that is to assess effectiveness and efficiency of actions or existing strategy with the link to the further decision-making process based on the values of quantitative and qualitative indicators. Moreover, based on the reported results some decisions to improve daily operations alongside with strategic decisions to influence the long-term performance in positive way can be made (Atkinson et al., 1997; Rezaei et al., 2011).

Table 6

Comparison of “performance measurement” definitions

Source	**Composite elements mentioned in “performance measurement” definitions**				
	Assessing effectiveness and efficiency	Performance quantitative indicators	Performance qualitative indicators	Strategic planning	Link to decision making
Neely et al. (1995)	∨	∨	∨	(∨)	
Atkinson et al. (1997)	(∨)			∨	∨
Kerssens-Van Drongelen and Fisscher (2003)	∨				(∨)
Moullin (2007)	∨			(∨)	
Rezaei et al.	∨	∨			∨

(2011)					
Aracioglu et al. (2013)	(∨)	(∨)	(∨)	∨	∨
Ivanov and Avasilcai (2014)	∨			∨	(∨)
Balaboniene and Vecerskiene (2015)	∨			(∨)	∨
Nappi and Rozenfeld (2015)	∨	∨		∨	∨
Zamecnik and Rajnoha (2015)	∨	∨	∨		(∨)

* ∨ component is explicitly mentioned in the definition
(∨) component is not explicitly mentioned, but is implied in the definition

Finally, based on the analysis of the set of definitions it is assumed that performance measurement is the process of data analysis and its interpretation with the use of both quantitative and qualitative indicators that has the aim of assessing effectiveness and efficiency of actions and taking reasonable decisions.

The model refers to the specific draft or basic scheme that can be implemented and used in the future for certain situations. In general, the model should present some patterns or standards that can be applied in practice.

All in all, in order to develop the performance management model for smart cities (that also includes performance measurement aspects), it is necessary to collect information about short-term and long-term goals of intelligent cities and to identify which KPIs are used to assess the performance of smart cities and how successful they are in helping to achieve the goals previously set.

1.4. Identifying the research gap

Nowadays it can be quite difficult to analyze critically the research made and scientific articles about performance measurement of smart city activities and also classify them into different groups according with approach peculiarities as there are still not so many literatures devoted to this topic. It is connected also with the fact that in practice there is no one single clear understanding of how ideal intellectual city should look like. Scientists, IT managers and all the staff who are involved in the process of building the cities of new generation sometimes do not know which way of organizing some activities or implementing some new technologies will be

correct and more effective one. And if there is no clear picture about how the process of creating smart city and its strategy realization should look like, it can be very complicated to assess the effectiveness and smartness of activities inside this town and also it can be quite difficult to measure the overall performance of the whole city.

Despite this evident problem, there are few scientific sources that provide some ideas about performance measurement of smart cities. These existing sources recommend a number of indicators and ratios to be used for giving feedback on the effectiveness of smart systems and smart technologies. All these indicators and ratios can be divided into two groups by their type - qualitative and quantitative.

Qualitative data deals with descriptions, can be observed but cannot be measured or calculated. That makes the process of information analysis more complicated and subjective. However, quantitative data is always presented with some numbers or ratios so this type of data can be easily measured, presented in figures and used to construct some models.

The business model matrix with the qualitative indicators for smart cities was presented in 2015 (Walravens, 2015). The current matrix can be used as an analytical tool in some cases for innovation ecosystems or even collaborative arrangements that provide customers with solutions combined by several companies with their individual offerings (Adner, 2006). This matrix is applicable for mobile services and applications what limits its practical adaptation. All the indicators presented in this business model matrix are divided and organized into two levels. The first level presents the connection with smart city goals that are set by policy makers while the second organizational level corresponds to ways of how governments are organized to reach those goals (Table 7).

The governance parameters related to the value network include good governance (political motivation in offering various services to citizens, rights of citizens and their protection) and stakeholder management (involvement of stakeholders in the process of bringing a service to end user). The governance parameters related to the technical architecture are technology governance (the importance of transparency and participation in making any technological choices by public entities) and public data ownership (controlling the terms under which the data is open to various actors). The public value parameters related to the financial architecture are return on public investment (the expected value generated by a public investment) and public partnership model (building of financial relationships between public and private participants in the value network). The public value parameters related to the value proposition are public value creation (examination of public value from the end user perspective) and public value evaluation (the question if an evaluation is performed of the public value the government sets out to create).

Table 7

Business model matrix (Walravens, 2015)

	Value Network	Technical Architecture	Financial Architecture	Value Proposition
Business Design Parameters	**Control Parameters**		**Value Parameters**	
	Control over assets	**Modularity**	**Investment structure**	**User involvement**
	Ownership VS Consortium Exclusive VS Other influence	Modular VS integrated	Concentrated VS distributed	Enabled, Encouraged, Dissuaded or Blocked
	Vertical Integration	**Distribution of intelligence**	**Revenue model**	**Intended value**
	Integrated VS Disintegrated	Centralized VS distributed	Direct VS indirect	Price/ Quality Lock-in Effects
	Control over customers	**Interoperability**	**Revenue sharing**	**Positioning**
	Direct VS mediated Profile & Identity management	Enabled, Encouraged, Dissuaded or Blocked	Yes or no	Complements VS substitutes Branding
Public design parameters	**Governance parameters**		**Public value parameters**	
Policy goals	**Good governance**	**Technology governance**	**ROPI**	**Public value creation**
	Harmonising existing policy goals & regulation Accountability & trust	Inclusive VS exclusive Open VS closed data	Expectations on financial returns Multiplier effects	Public value justification Market failure motivation
Organizational	**Stakeholder management**	**Public data ownership**	**Public partnership model**	**Public value evaluation**
	Choices in (public) stakeholder involvement	Definition of conditions under which and with whom data is shared	PPP, PFI, PC…	Yes or no Public value testing

Another example of existing performance management models to be used for smart cities is the Civil Society sub-network that has been presented as the model to evaluate policy visions of smart cities (Nijkamp and Kourtik, 2011). As the figure below presents (Figure 3), there are four alternative city visions: the Connected City (advanced transportation infrastructures, smart logistic systems), the Entrepreneurial City (globalization policy, economic vitality), the Livable City (smart environmental and energy initiatives), and the Pioneer City (unprecedented cultural diversity and fragmentation of lifestyles). Moreover, the Civil-Society sub-network presents also five domains that can be crucial for giving the city a status of being smart urban settlement. These domains include smart governance, smart economy, smart human capital, smart living and smart environment. One of the key disadvantages of the current model is the lack of specific ratios that can be used to assess the level of the development of presented areas. So the Civil-Society sub-network presents just the components that state what city can be identified as "smart" and what kind of criteria it should meet in order to be effective.

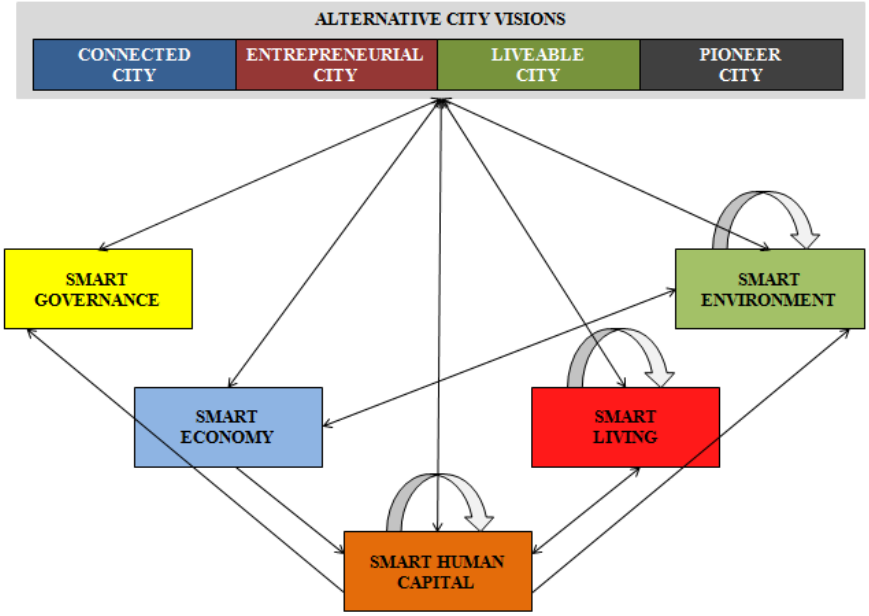

Figure 3 The Civil Society sub-network (Nijkamp and Kourtik, 2011)

Based on the analysis of the existing performance management models and approaches to evaluating the performance of smart cities the research gap was identified. The research gap is derived from the consequence of key disadvantages of performance management approaches presented above. First of all, there are no quantitative ratios presented in the structure of existing approaches to measure how the goals of smart city are achieved. Secondly, there is a poor mapping of smart city goals and KPIs to be used to assess the concrete goals.

To make the following steps much clearer and easier the research questions were formulated for the current research:

- What is the general practice in performance management of smart cities? Are there common smart city goals, and are there common KPIs to evaluate performance?
- Is there a generic performance management approach to describe the common practice of performance management of smart cities? What is the place of smart city goals and KPIs in this approach?
- Can the holistic performance management model be provided based on the practices of real smart cities?
- Can there any recommendation be suggested from the presented approach to advise on the implementation and further development of a performance management model in smart city?

Summarizing the information above and finalizing the literature review made, it should be emphasized that *the research gap* is connected with the lack of instruments to be used for performance management and measurement of smart cities. Considering the disadvantages of existing models, the key goal of current research is to identify indicators and ratios (both

qualitative and quantitative) that can be used to measure smart city performance and to combine them into the holistic performance management model that will be useful for the practical aims.

1.5. Summary of chapter I

First of all, in order to be more aware of the smart city context, in-depth analysis of the current topic was made. It was found out that nowadays there is the tendency of the rapid urbanization. According to United Nations study, more than 60% of the total world population will live in cities by 2050. Such the intense urban population growth became the reason for several urban problems that include traffic jams, air and water pollution and overconsumption of natural resources. Smart city is considered to be one of the most effective ways to solve such various urban problems. However, as the phenomenon of smart city is relatively new, there is still a lack of instruments that can be used to measure its performance.

The detailed literature review of the current topic reveled that there is still no one single definition of smart city. Based on the analysis of different approaches common components of smart city were defined which include the active use of ICT, the high-quality life of citizens, sustainable development, green environment, and smart government systems. To find out the different strategies of smart city development and management systems, practical examples of European, Asian and Russian smart cities were considered.

After the literature review all the information, definitions and thoughts about “smart city” concept were summarized in the graph (Figure 4) presented below to make the concept easier to understand. Today the “smart cities” topic is mainly connected and identified with green and eco environment, safety of citizens, smart transportation and logistics systems, city design, planning of daily operations, smart healthcare (making the process of hospital services easier and the process of treatment faster and more effective), smart education in kindergartens, schools and universities, smart infrastructure that makes the life inside the city faster and more comfortable, etc.

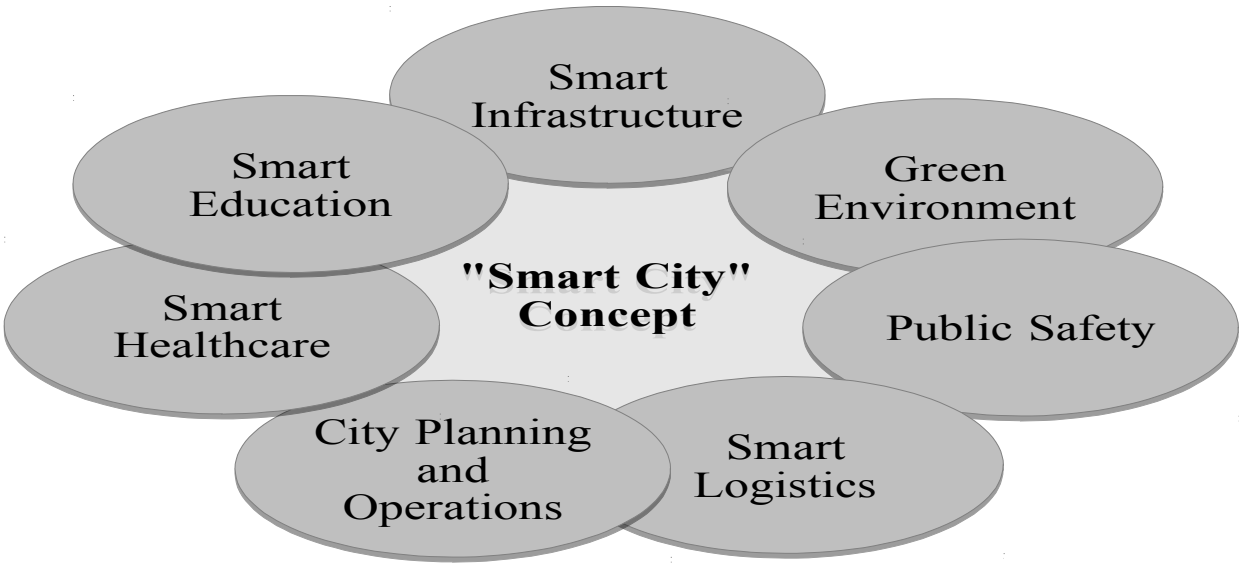

Figure 4 "Smart City" concept vision

Moreover, for the better understanding of the final results of the current research the literature review of performance management concept was conducted. Existing performance measurement models for smart cities were analyzed what helped to identify the research gap as current models use only qualitative ratios and do not make the clear connection between goals and KPIs.

Considering the lack of performance management systems for smart cities the goal of the current research was set as creating the model with KPIs that can be used to assess the performance of smart cities.

In order to achieve this goal the range of research questions were formulated. First of all, it is necessary to find out if any common practices for performance management of smart cities exist. Secondly, it should be researched if a holistic performance management model can be provided based on the practices and if any recommendations can be given based on the final model suggested.

The detailed analysis of performance management provided the understanding of future results of the current research as performance measurement is a part of the performance management process alongside with goal setting, reviewing and performance control.

2. METHODOLOGY

The second chapter will describe methodology of the current research. The detailed information about data collection methods, data collection process and samples for expert interviews and questionnaires will be provided in the current chapter. Furthermore, the detailed description of the five-level Performance Management Model (Samsonowa, 2012) created for R&D departments of ICT companies will be provided alongside with justification to use this model for performance management of smart cities.

2.1. Data collection methods

Nowadays, there are various types of researches that differ in topics and aspects. However, these researches are common in the fact that they all need some data to be collected and derive results, recommendations or conclusions based on information gathered.

In general, all the kinds of research can be divided into three categories that are quantitative, qualitative and mixed ones that combine both quantitative and qualitative research (Williams, 2007). Quantitative research uses statistical, computational or mathematical techniques in order to investigate the observable phenomena in the systematic empirical way. Main objectives of such quantitative research are to develop mathematical theories and hypotheses that explain phenomena and that can be used in the future to make predictions (Creswell, 2003). Qualitative research has aim to explore some topic through non-numerical tools and expert evaluations (Williams, 2007).

The current research presents the combination of research types that include the case study as the method to conduct qualitative research and the survey in the form of the questionnaire as the method of mixed research including both quantitative and qualitative research.

The instruments chosen for the research are valid and reliable. The validity and reliability can be explained through the type of research that aims to identify practices of developing the list of criteria of city “smartness”, performance measurement indicators already existing and analyzing the current situation and further suggest the performance management and measurement model for smart cities.

The case study as the first step of the research process is based on the published report that investigates a certain phenomenon that has been studied over time (Thomas, 2011). The case study as a research strategy relies on multiple source of evidence (Creswell, 2009). The data sources for case studies include expert interviews and available documents. Since the interview is a process of exchanging views between two or more individuals on a topic of mutual interest

(Kvale, 1996), the interview can be identified as the systematic way of talking with and listening to people or as a way of collecting data from people through conversations.

There are several reasons to use interviews as the data collection method and the research instrument (Gray, 2004):

- a need to attain highly personalized data;
- importance of good return rate;
- opportunities are required for probing;
- respondents are not fluent in the native language of the country, or where they have difficulties with written language.

Four major types of interviews are widely spread nowadays differing from each other by types of questions, aims and the general format of interview. These types are:

- the structured interview (the standardized interview where the same questions with the same wording and in the same sequence are asked from respondents (Bryman, 2001)),
- the unstructured interview (the non-directed interview; the flexible method in which interviews are different and do not require certain guidelines);
- the semi-structured interview (the non-standardized interview not only with guidelines, but also with the possibility to ask additional questions);
- the non-directive interview (the interview with no preset topics to pursue and no pre-planned questions during which the interviewee leads the conversation) (Gray, 2004).

To accomplish research the semi-structured form of interviews with experts in the field of smart cities construction and development was chosen. Such interviews are non-standardized and frequently used in the qualitative analysis. In this case the researcher has a list of key themes to be covered, issues and questions to be discussed. An interview guide is used but additional questions still can be asked (Appendix 1). Within each topic the interviewer is free to conduct the conversation based on own preferences, explain questions or ask to clarify some answers if needed (Corbetta, 2003).

This type of interview suits current research the most because it gives more freedom in comparison with a structured interview in which the interviewer has to adhere to a detailed interview guide (Kajornboon, 2004). Another advantage of semi-structured interviews is the fact that the researcher has the opportunity to prompt and go deeper into the given question, while key questions from the interview guideline must not be missed in order to construct the better performance management and measurement model. In addition, the researcher can explain or rephrase the question if the respondent is unsure about the meaning of the posed question.

Table 8

Intentional and extensional definitions of the interview

Intentional definition	Extensional definition
A conversation in which one person elicits information from another person	• Telephone interview • Face-to-face interview • Panel interview • Group interview

All in all, the interview as a method to be used for accomplishing current research is described in the Table 8 by means of intentional and extensional definitions. Concluding all the points above, it is possible to define the interview as a conversation in which one person has the aim to elicit some necessary information from another person he or she is talking with. The extensional definition provides several examples of interviews such as telephone interviews face-to-face interviews, panel interviews, or group interviews.

After the interview with experts the conceptual performance management model is going will be created. This model will be validated with a data collection tool such as a questionnaire oriented on the large sample. The questionnaire is a data collection instrument that represents the systematically prepared form or document with a number of questions intentionally designed to detect responses from respondents or research informants with the purpose of collecting necessary data or information (Bryman and Bell, 2003).

There are two main types of questionnaires: unstructured (open ended forms) and structured (closed forms) different in the forms of questions that constitute the questionnaire.

The unstructured questionnaire also often named as the unrestricted type of questionnaire or the open-ended one calls for free responses in the own words of the respondent. Such forms of open-ended questions give the respondent the opportunity to express his or her point of view through a set of options. This type of questionnaires requires more time and may not be suitable for some researches since some of respondents may refuse to participate in the questionnaire (that will immediately decrease a number of answers).

The current research assumes to make the questionnaire for quite a wide sample of respondents in order to gain more valid results. Due to this reason the second type of questionnaires, the structured one was chosen to fulfill current research. Structured questionnaires give more control or guidance for the answer of the respondent. This type can be described as a closed form because the questions require the respondent to give answers like ‘yes’ or ‘no’ or simply check an item out of a list of given responses. Those questions that require ‘yes’ or ‘no’ answers are also named as dichotomous questions. There also can be multiple-choice questions for which the respondent selects the answer that is very close to his or her opinion. It means that the choice of the respondent is limited to the set of options provided,

however, such kind of questionnaires saves the respondent's time and do not require extended answers. To conclude, the structured questionnaire of the closed form was chosen as a research tool with the objective to check the model built previously based on expert interviews.

Table 9

Intentional and extensional definitions of the questionnaire

Intentional definition	Extensional definition
A series of questions with the aim of extracting necessary information	• Open ended questionnaire • Closed questionnaire

The same as for interviews the table with intentional and extensional definitions (Table 9) is presented above. The questionnaire can be identified as a paper with a series of questions with the aim of extracting some necessary information to be used later for the research (or other) objectives. Examples of questionnaires are presented through the extensional definition: the most popular forms of questionnaires are open-ended questionnaires (unstructured) and closed questionnaires (structured).

Expert interviews and questionnaires that were chosen as data collection methods for current research allow identifying not theoretical but practical gaps, advantages and disadvantages of real models and give the understanding of how the optimal model should look like. Finally, interviews and questionnaires give the opportunity to extract data that is not available in open sources.

2.2. A five-level Performance Management Model description

As a basis for the Performance Management Model for smart cities a five-level Performance Management Model (Samsonowa, 2012) presented for research and development (R&D) departments of ICT companies and including five levels will be used (Figure 5). This model is considered as a model comprising the relations between inputs, activities, outputs and outcomes of a separate research department inside an enterprise.

Performance measurement relates to a continuous weighting of a defined company's business goal on the one side and the degree of its achievement on the other side. Fundamentally, goals and the goal setting process can be considered at three various levels: the strategic level (answering the question of where to go), the tactical level (answering the question of what to do) and the operational level (answering the question of how to do).

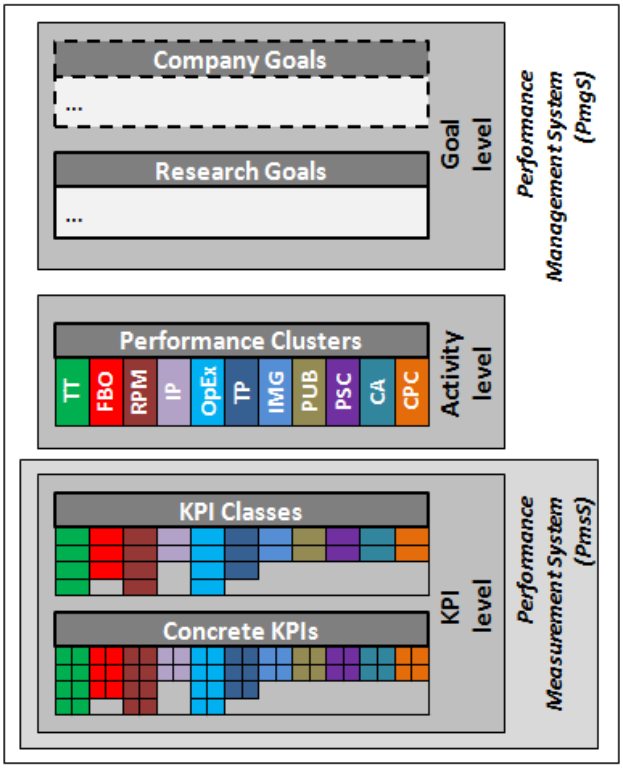

Figure 5 A five-level Performance Management Model (Samsonowa, 2012)

In general, all the levels can be divided into two parts. The first part named as the Performance Management System (PMgS) consists of three levels. Level one and level two are presented with Company goals and Research goals. They can be combined because both present the Goal level and set strategic goals that answer the question of 'where to go?' for the company on a whole. These goals that are usually quite broad and long-term define the vision of the company or the entire function. Research goals are more narrow and precise because they depend on the exact area and peculiarities of the project. It is obvious that in this case research goals (the second level of model) follow objectives of the organization and do not contradict company's goals, vision and mission.

The Activity level of PMgS represents eleven Performance clusters that include technology transfer, future business opportunities, research portfolio management, intellectual property creation, operational excellence, talent pool, image, publications, presence in scientific community, collaboration with academia, collaboration with partners and customers.

The second part of Model is presented through Performance Measurement System (PMsS) that consists of KPI Classes and Concrete KPIs. As it is possible to understand from the names these levels are combined as KPI ones. After the step when key activities are defined, criteria to assess those activities need to be identified. All in all, final level requires defining and using of concrete methods (indictors, ratios, etc.) that can measure performance.

In order to be used later during empirical research this five-level Performance Management Model for R&D departments, presented previously, should be reviewed from the prospect of smart city. While it is also important to understand the background if this model can be transferred to the practice of smart cities. Adaptation of the model from organizational (departmental) use to city administration is relevant due to the similar logic in functioning and development of different units while city can be considered as an organizational unit. Moreover, R&D industry is close to smart city and smart initiatives because of the active use of ICT as instruments to enhance performance and improve efficiency and effectiveness of organizational unit.

Furthermore, such drawbacks of existing performance measurement models for smart cities as absence of quantitative ratios and lack of correlation between smart city goals and KPIs makes the performance evaluating quite subjective and incomplete. That justifies the choice of the methods applied for the current research as one of the key advantages of this five-level Performance Management Model is direct mapping of KPIs to specific goals that are going to be assessed. Overall, final Performance Management Model for smart cities also consists of five levels as original Model that is used for R&D departments (Samsonowa, 2012).

The very first level of company's goals can be implemented for the country level since each government strives to develop steadily, protect rights of citizens and become politically and economically stable.

The second research level explains smart city goals as smart cities represent the part of the country and specific cities have their own goals and objectives to be reached. While the goals of different smart cities can be very similar as these cities belong to one common category, some components can still differ and depend on the economic, political, and social peculiarities of the city, its vision and mission.

The Activity level is closely connected with key functions of smart cities distributed among different city committees. Nowadays, almost all cities have the similar structure of the administration. It usually includes the Committee of economic development and finance, the Education Committee, the Committee on Industry, the Committee on Social Policy, the Construction Committee, the Committee on Transport and Logistics, the Committee on Culture, the Committee on Public Security. Smart city objectives and domains of each Committee are different and depend on functions and areas the Committee deals with.

The last two levels present performance measurement system which is going to be one of the outputs of the Master thesis in the form of performance management model. So criteria for performance assessment and specific indicators or ratios depend on performance goals and their peculiarities that Committee sets. These KPIs are presented through empirical study in Chapter

III. They are also divided into groups depending on indicators' characteristics and types of activities of exact city Committee.

The correct company's goals, which any performing department attempts to achieve, should contain targets to be reached, as well as some elements of time at which the milestones or target to that time are reached and also rules about a preference ordering about the ways to get there. The three elements indicate organizational goals and the definition of performance rest on the definition of a causal model linking inputs and outcomes through selected causal relationships. For example, as it is possible to see the performance clusters (that are the third level within the five-level Performance Management Model), represent the important link connecting the two ends: organizational goals and performance measurement.

The same logic can be implemented for smart cities. The correct country goals, which any existing city inside this country attempts to achieve, should contain some certain list of targets to be reached. The objectives and plans of Committees should follow vision and both short- and long-term plans of the single smart city and must not contradict them.

2.3. Data collection process and sample description

For the purpose of efficient data collection during expert interview an interview guide was created. In general, the interview guide that should avoid any ambiguity presents a list of questions, topics and issues the researcher would like to cover during the interview. Prior to interviews, convenient guidelines for their conduction were created to make the interview output more reliable.

The interview guide with the draft of questions to be asked is presented in Appendix 1. The interview with representatives of smart cities consists of several parts. The very first part includes questions about personal data of experts such as job titles, positions in the smart city administration and responsibilities. This information is important for the better understanding of how exact respondents participate in smart city development and what exact area the respondent manages.

The second block of questions is closely connected with the first part of the five-level Performance Management Model presented before. The aim of this block is to identify what goals the smart city sets to be achieved. Also, it is necessary to understand if different committees of the particular smart city have a different list of goals to be accomplished till the end of the month or the year. It may be assumed that goals of various committees should follow general goals of the smart city and not contradicting the city's vision of development. The point for measuring the goal achievement will be identified.

Another block of questions has the aim to gain information about performance measurement tools or the whole performance measurement system being applied in the particular smart city. The respondents were asked to describe the performance measurement tools or system, the process of how the city evaluates the goals achieved or how it plans to work in the future (depending on the stage of development of the smart city). It was also meaningful to examine the origin of such tools or system, in particular, whether the smart city created the performance measurement system on its own or used the experience of other cities. The problems and disadvantages of the current system could be analyzed to define how they could be eliminated in the future to avoid these mistakes and drawbacks while creating the Performance Measurement Model as the output of current research. During the research process the number of key performance indicators (KPIs) that this smart city uses were identified and what they exactly measure was revealed. The insight into distinguishing short- and long-term KPIs gave a clear understanding of how different indicators can be used for evaluation of effectiveness of smart city activities. Furthermore, the frequency of collecting and analyzing various indicators and ratios was identified. Finally, forecast aspects for future development in performance measurement models were considered.

If the smart city does not use any performance measurement tools, models or specific ratios to evaluate its performance, it was useful to reveal and analyze the underlying reasons for that situation and define the ideal model to be used for performance measurement of the smart city in the future.

The last set of interview questions concentrates on analyzing how KPIs of separate Committees are derived from KPIs of the smart city and how they reflect the critical success factors of the smart city.

The further step after expert interviews and analysis of documents available is creating conceptual performance management model to be used for smart cities. Logic models as one of the techniques to combine and synthesize results of multi case studies can be based on the number of cases from two and more (Yin, 2003). The use of models as analytic technique assumes creating theoretical models based on practical examples of several case studies. The sample for case studies includes existing smart cities that work continuously on the implementation and realization smart city strategy. The expert interviews to collect data for case studies were conducted with the representatives of smart city administration or managers of smart city initiatives (Table 10).

Table 10

Sample description for expert interviews

Expert name	City name	Respondent position
Hans Christian Christiansen	Copenhagen	Senior Adviser, The Technical and Environmental Administration, City Development/ Municipal planning
Eva Pangerl	Vienna	Municipality of the City of Vienna, Department MA 18 Urban Development and Planning, Smart City Wien
Po Chi Wu	Hong Kong	Vice-Chairman, Invotech
The respondent wished to keep the name unknown	Innopolis	Smart city manager

The additional method of data collection, the questionnaire used to validate the performance management model built based on case studies data consisted of both close and open-ended questions to give the opportunity for respondents to express their own opinion and fill in the model with their suggestions. The types of questions included into the survey are:

- multiple choice questions with the comment box;
- questions with the matrix or rating scale with the comment box.

As the questionnaire was supposed to be conducted among 100 respondents it should not have taken too much to get more feedback. Furthermore, with the aim of getting more valuable and adequate results the respondent was aware about smart cities development, functioning, design and construction. The sample for questionnaire included representatives of IT companies that conduct separate smart projects and create solutions for intelligent urban settlements, representatives of IT and research universities, both international and Russian companies (Table 11).

Table 11

Sample description for questionnaire

Company name	Country	Brief description
IBM	USA	producer of computer hardware, middleware and software, and consultant in services in nanotechnology
AGT	Switzerland	IoT and Social data management, Big Data integration and advanced analytics
ITMO	Russia	St. Petersburg National Research University of Information technologies, mechanics and optics
AECOM	USA	worldwide provider of Professional Technical Services and Management Support Services to markets of Infrastructure, Transportation, Facilities, Environmental, Energy, and Water
Ingria	Russia	business incubator as a structural unit of St.Petersburg Technopark managing high-tech projects
JetBrains	Czech Republic	software development company that targets software developers and project managers

Table 11 (continuation)

IAC SPb	Russia	an enterprise working in the field of informatization and providing information and analytical support of local authorities of the City of St. Petersburg
Leontief Center	Russia	independent research and consulting organization in the areas of science, information technologies and telecommunication
Cisco	USA	technology company that designs, manufactures and sells networking equipment
Start Development	Russia	implementation of development projects in the urban and suburban real estate
St. Petersburg Polytechnic University	Russia	National research technical University
University of Thessaly	Greece	the University with Schools of Humanities and Social Sciences, Engineering, Agricultural Sciences, Health Sciences, Physical Education and Sport Sciences, and Sciences
AEM-technology	Russia	mechanical engineering division of ROSATOM state corporation in the field of power engineering
NEOTEX	Russia	services directly related to the transfer and commercialization of technology and other related services
IzhoraRemServis	Russia	integrated solutions for industrial enterprises in the field of maintenance and repair
Krylov State Research Center	Russia	one of the world's major ship research & design centres with century-long efforts in the field of innovative R&Ds for the benefit of national shipbuilding
ITERANET	Russia	a full-featured system integrator and service in the field of communication and computer technologies
St.Petersburg University of Technology and Design	Russia	the largest university in the Russian artistic and technological profile
EMC	USA	computer data storage company
Smart City Council	USA	an advisor and market accelerator that promotes the move to smart, sustainable cities
Intel	USA	multinational technology company producing motherboard chipsets, network interface controllers and other devices related to communications and computing
Siemens	Germany	engineering company with the principal divisions of Industry, Energy, Healthcare, and Infrastructure & Cities

The respondents of the questionnaire can be described with the origin of the company or University. All the sample representatives are divided into Russian and non-Russian organization that illustrates the presence of Russian smart city context in the current research (Figure 6). From the figure provided below it is possible to conclude that more than half or survey respondents present Russian companies and Universities.

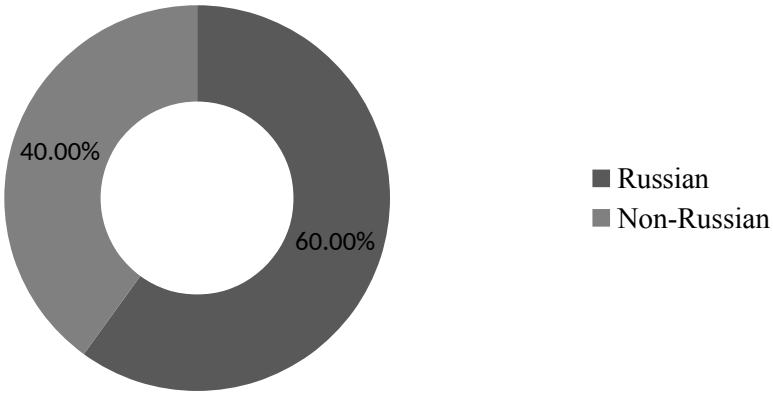

Figure 6 Location of organization headquarter

All the methods described above were supposed to facilitate distinguishing performance management and measurement tools or systems that are used in practice, motives for their use, existing problems and possible ways to create the optimal model.

2.4. Summary of chapter II

The current chapter of the master thesis covers the description of methods applied for data collection and creation of the performance management and measurement model described further in Chapter III. Key tools used for data collection are qualitative including expert interviews and questionnaires oriented on the wider sample and used to prove the results of the conceptual model.

As the base for the final Performance Management and Measurement Model a five-level Performance Management Model (Samsonowa, 2012) was used. This Model was initially developed for research departments of a company, however, in the context of the current master thesis the Model was implemented for smart cities.

In general, a five-level Performance Management Model consists of two parts that are Performance Management System (three levels) and Performance Measurement System (two levels). Towards the performance management model for smart city, the first level of the Model presents global goals of the government as legal unit. The second level explains smart city goals as smart city as a single unit of the country has the set of the goals and objectives that also should not contradict the country goals. Activity level is closely connected with key functions of smart cities that are distributed among different city committees and presents through various smart city domains. The last two levels present performance measurement system which is going to be one of the outputs of the Master Thesis in the form of Performance Measurement Model. So criteria for performance assessment and specific indicators or ratios depend on performance goals and their peculiarities that Committee sets.

Qualitative methods of data collection used in research had the aim to explore the problem through non-numerical tools and expert evaluations. Interviews and questionnaires gave the possibility to analyze the current situation with existing practice of using performance measurement models and tools in smart cities that have already been developed or just will be created. The instruments chosen for the research are valid and reliable.

Interviews were held with experts from smart cities construction and development fields. During the research process it was identified whether the status "smart" could be attributed to the city of new generation, what qualitative or quantitative indicators and practices already exist for measuring performance and success of smart cities both in Russia and abroad.

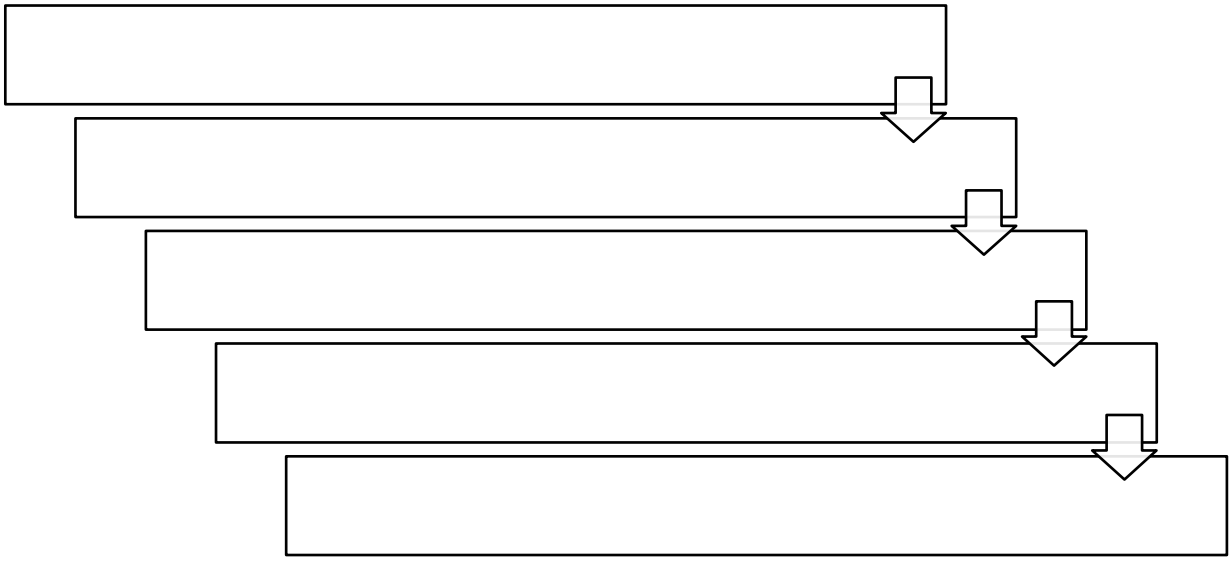

Figure 7 Plan of empirical study

As it is summarized with the Figure 7 above the first step of data collection represents interviews with experts who manage new smart cities projects in Russia and also abroad. The interview guideline is presented in Appendix 1 that helps to understand the interview key topics and most important questions. After interviews preliminary model is going to be created with qualitative and quantitative indicators that can assess performance of smart cities.

In order to check conceptual model questionnaires are organized for wider sample of respondents who are also dealing in the smart cities development areas. Questionnaire is supposed to be structured one that means it consists of closed multiple choice questions with possibility to add the own answer of respondent if it is not found in the range of suggested. The multiple choice questions and matrix forms are better options to be used for the survey structure as all the questions are based on the conceptual performance management model for smart cities constructed previously from case studies.

The final step after interviews and questionnaires conducted is creating Performance management & measurement model that can be used in practice to evaluate effectiveness of

operations inside smart cities. This model is key output of current Master Thesis that has both theoretical and practical value. The results of empirical study are presented in Chapter III below.

3. RESEARCH FINDINGS

The current chapter will present key findings of research alongside with final results achieved. Firstly, goals and smart city domains found from case studies of smart cities and questionnaire results will be described. Secondly, detailed specification of KPI classes to be used to assess specific domains of smart cities will be suggested. Finally, managerial implications and recommendations for smart city managers will be proposed in the third chapter.

3.1. Goals and smart city domains

Data on practical performance management and measurement models and also concrete KPIs that were used by smart cities was collected following two key steps. Based on the structure and components of 5-level Performance Management Model (Samsonowa, 2012) a set of questions was developed and presented in the chapter II of current master thesis. The results of expert interviews present performance goals of smart city initiatives and also specific KPIs that are used to assess the performance of smart city.

Based on detailed responses of the smart cities representatives it was summarized which strategy smart cities were following; what performance goals were set to follow the strategy of making the city "smarter"; what qualitative and quantitative indicators were used by the smart city administration to assess the city performance. Moreover, in-depth research of performance goals from different smart cities experiences allows to understand that all the smart city initiatives, in general, can be quite similar in the sense that these smart cities aim to serve and improve similar city areas and domains in spite of the fact that those smart city initiatives can be different due to political, economical, and cultural peculiarities.

The overall strategy and key goals of a smart city are presented as the Smart City Goal part of the Goal level in the final five-level Performance Management Model to be used for smart cities (Figure 8). According to analysis of the practical examples this kind of the smart city goal is quite individual and highly depends on city specifics.

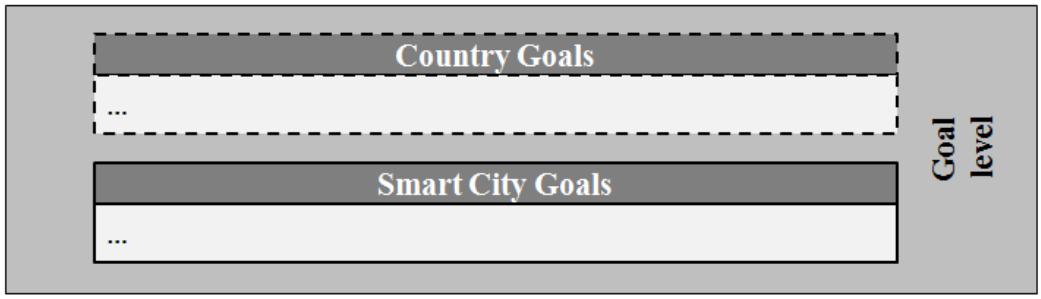

Figure 8 Goal level of Performance Management Model for smart cities

Copenhagen sets the ambitious plan to become the world's first carbon neutral capital by the year 2025. Such a plan requires long-term actions; however, it is still realistic as the statistics show that in 2011 Copenhagen was able to reduce CO_2 emissions by more than 20% compared to 2005. In order to follow this smart city goal, the Climate plan was developed and introduced by the City Council in 2009. This official framework presents the detailed action plan with specific objectives of how the goal of carbon neutrality can be achieved successfully by 2025. Mainly, the Copenhagen smart city goal is going to be achieved through smart energy consumption and production alongside enhancing the level of green mobility, smart water usage and also attracting citizens to participate actively in smart city projects and solutions (CPH 2025 Climate Plan, 2012).

Hong Kong in its "Smarter Hong Kong, Smarter Living" Strategy outlines the framework for the City to leverage on new technologies to stimulate further continuous economic development, build platforms for collaboration, communication and sharing, deliver integrated e-services to the citizens and foster the ICT industry. It is a living strategy that grows and evolves continuously alongside the global trends and aspirations of the Hong Kong community (Public Consultation on 2014 Digital 21 Strategy, 2013).

The key objective of the Vienna smart city that is also announced as the long-term smart strategy to be implemented till 2050 is to provide the best quality of living for all its citizens along with maximum resource saving brought about by extensive and complex innovations. That assumes Vienna to become the city of green spaces and renewable energy, one of the most successful and attractive hubs in Europe for young people from all over the world, and also the city of equal opportunities for citizens of all the generations (Smart City Wien, 2014).

The case studies for each smart city of Copenhagen, Vienna, Hong Kong and Innopolis summarize the data collected from expert interviews and documents available about smart city strategy implementation (Appendix 2). All case studies have the same structure which is used to create the final Five-level Performance Management Model for smart cities (Table 12).

Table 12

Case study outline

Case element	**Description of content**
City Profile	Brief description of the city itself
Smart city initiative profile	Description of management systems of smart city initiatives
Smart city domains	Domains of smart city goals and functioning
Smart city KPIs	List of KPI classes and concrete KPIs
Mapping goals and KPIs	List of KPIs to assess specific smart city goals
Conclusions	Analysis of the existing instruments to assess smart city performance alongside with drawbacks of current performance measurement systems

All in all, analysis and comparison of goals of Copenhagen, Hong Kong, Vienna and Innopolis served as the basis for indication of performance goals that can be used in the Activity level of the 5-level final Performance Management Model. In general, the list of six performance goals is defined through identification and analysis of both common points and differences of three smart cities used in the sample. The six smart city domains identified include the following (Figure 9):

- Green environment;
- Resources and energy;
- Quality of citizens living;
- ICT innovations;
- Business and entrepreneurs;
- Smart government.

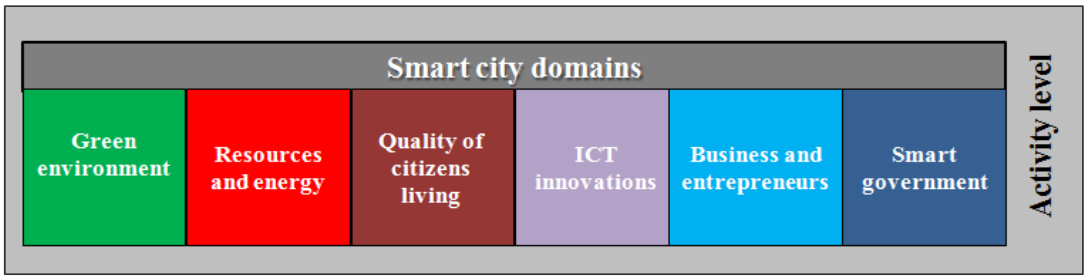

Figure 9 Performance goals of smart cities

The use of resources and energy in an effective way as a single performance goal of smart city can be also allocated into different domain. Basically, smart resources assume the way how natural and artificial resources and city assets are used. It is also closely connected with sustainable development of the city on a whole that means interrelation between effective uses of resources in the current period of time and saving these resources in the appropriate condition for the future generation. One of the way to deal with the current goal domain is also the active use of renewable energy sources as it is presented in the case of the Copenhagen smart city strategy (City of Copenhagen: City Hall, 2014).

The effective implementation of the strategy of smart resources and energy depends not only on solutions from the city management side but on citizens' inclusion. The effective use of energy assumes saving watts per capita to serve housing services such as heating, cooling, etc.

Maintenance of green environment is another great part in the list of smart city performance goals. This domain like the effective use of resources and energy correlates with sustainable development of smart city and preserving the environment healthy and green not only for present but also for next generations.

In general, key environmental problems include air pollution, water pollution, and a lack of green areas around the city territories. In order to deal with these problems specific green solutions should to be implemented in the context of the city development strategy. For example, such smart green projects and solutions can be connected with waste recycling, development of the culture of using CO_2-free modes such as bicycles or electrical cars.

Enhancing the quality of citizens living is one of the key aims of smart cities considered as a reason for smart city initiatives to be implemented all over the world. This performance goal of smart cities basically includes improving various city services in order to make the life of citizens easier and more comfortable. That can assume availability and the higher quality of healthcare services, transport and logistics services, level of education.

Also the quality of citizens' living can have strong correlation with intensity and availability of ICT tools that aim to serve some public services. It is explained by the fact that such innovative instruments and electronic devices tend to make the most of procedures much easier and less time-consuming.

Implementation of ICT innovations in various city areas is a straight forward consequence of the goal of enhancing the quality of citizens living. Such ICT innovations are very important to be actively implemented and used by citizens in various public services. However, it also relates to businesses and even private life. From the expert interviews it was identified that the smart city strategy of Hong Kong mostly relies on active implementation of ICT tools into different areas of the city (Hong Kong: Commerce and Economic Development Bureau, 2014).

Supporting the business and enterprise in case with smart cities assumes not just finance support and investments into businesses from the government and city administration side. It is mostly connected with creating a range of IT services for companies to communicate with each other, with consumers and also with city management. Such IT services can include multi-sided platforms where one side is the city administration or cloud services.

Development of smart government systems actually takes a very important place in the set of smart city goals and the overall strategy as a great number of smart projects and solutions can be initiated by city managers. While following a number of steps to achieve the current goal of smart government some aspects need to be considered. For example, they can reflect how open the government agencies are in terms of communications and data sharing with citizens that is also connected with administration flexibility and dynamics. Furthermore, the intensity of various ICT tools use in government functioning plays a very important role with the aim of making a range of administration procedures much easier and less time-consuming.

The questionnaire results prove the conceptual five-level Performance Management Model built based on the findings from Copenhagen, Hong Kong, Vienna, and Innopolis case studies. All smart city domains are marked as important for the successful realization and implementation of the smart city strategy in practice and also should be assessed by city managers for further development (Figure 10). The top three domains with high priority to be evaluated include Quality of citizens living, Resources and energy, and ICT innovations. While domains with highest percentage of answers to be considered as the goals of low priority are "Smart government" and "Business and enterprise". Besides, no more additional smart city goals are suggested by survey respondents what can justify the completeness of the Activity level of the Model.

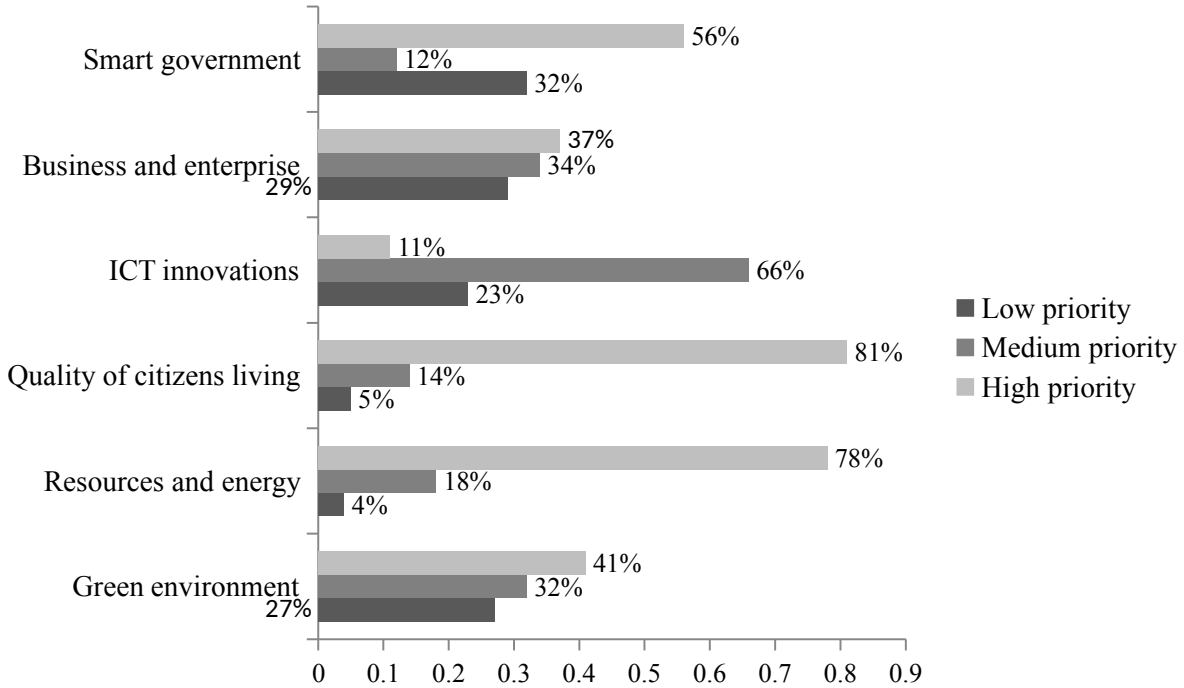

Figure 10 The importance of smart city domains

However, it is quite important to remember that smart city goals need to be reconsidered periodically in order to match with higher level goals o such as country and regional goals. In addition, the systematical smart city goals reconsideration allows moving with the times while considering all the economic, political, social, and ecological circumstances not only in the particular city but also in the concrete country or even globally. According to the questionnaire findings the dominant group of responses with the 42% of answers assumes to reconsider smart city goals once every three years (Figure 11). The further most populous groups are respondents who believe that smart city goals should be reconsidered once every two years (29%) or once a year (14%). While also several answers in the category of "other" assume to reconsider goals of intellectual city once every 10-15 years that makes the link between smart city goals and its strategy closer.

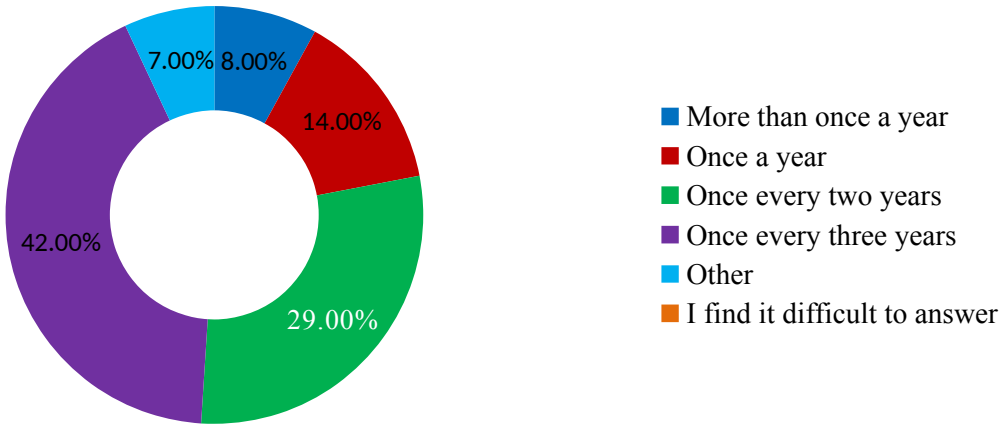

Figure 11 Frequency to reconsider smart city goals

The results of the mass survey with the representatives of both Russian and international IT companies and computer science universities proved the model built based on expert interviews. All the performance smart city goals were mentioned as the important ones and also relevant for the intelligent urban settlements almost in the same proportions.

3.2. Mapping goals and KPIs

As it is mentioned in the original five-level Performance Management Model for R&D departments (Samsonowa, 2012), the Performance Management System consists of Goal level and Activity levels that include performance goals. While the Performance Measurement System of the model is presented with the KPI level where KPI Classes are connected with performance goals founded out previously and are divided into concrete KPIs.

Based on the data collected through expert interviews and the questionnaire six performance goals of smart city were identified. Furthermore, each performance goal can be assessed with a range of qualitative and quantitative KPIs. To make the performance measurement process more detailed, the concrete KPIs are divided into KPI classes according to their common domains what allows ensuring that all the city areas are covered. All in all, KPI classes and Concrete KPIs are the parts of the KPI level of the final Performance Management Model and present the Performance Measurement System of this model (Figure 12).

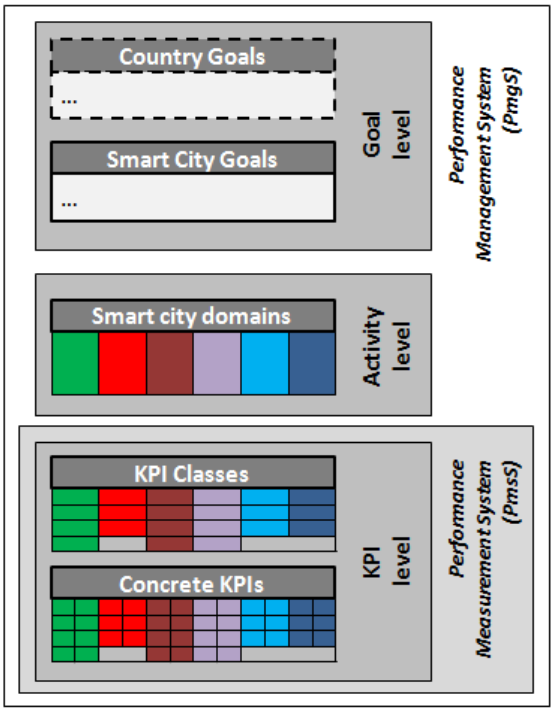

Figure 12 A five-level Performance Management Model for smart cities

The first performance goal which is "Using of resources and energy in effective way" is mapped with four KPI classes. First of all, as one of this goal component is the effective use of energy, the first KPI cluster tends to combine ratios that aim to evaluate effectiveness of energy use. For the city that strives to decrease losses in energy consumption it is important to control the energy consumption of each citizen in watt during the certain period of time (f. e., daily, weekly, monthly or annually). This ratio depends mostly on the personal attitude and contribution of each citizen into the city's smart strategy realization. Moreover, that concerns not only how the basic energy sources are used by citizens but also the intensity of renewable energy sources use in gross energy consumption. It leads to the development of the renewable energy infrastructure and switching from consumption of standard energy sources to consumption of electricity produced by wind turbines.

However, by the resources smart cities mean not only natural resources but also other city assets that include residential and commercial buildings on the city territory. That justifies the necessity to distinguish the layout and overall convenience of buildings as a separate KPI class. The buildings present a part of the city infrastructure used by citizens. It assumes that these buildings in urban areas should be attractive for the citizens. Moreover, all the city constructions should operate effectively in terms of energy consumption for different in-house services such as cooling, space heating, water heating that makes connection with the previous KPI cluster of the effective energy use.

The overall city infrastructure is another important city asset. It reflects how well the Internet infrastructure works with the density level of Wi-Fi points around the city area and the space covered with Wi-Fi points. Moreover, the development of sport facilities and special sport zones play the very important role in ensuring the higher quality of citizens' life. City infrastructure development also includes availability of parks and green zones for the city population alongside with the total square meters covered by green zones.

Four KPI class suggested for the assessment of the performance goal such as the effective use of resources and energy is the layout and the overall level of development of transport systems as they are considered to be one of the most important city resources. For individuals it is valuable to spend less time in traffic jams that can be achieved through high-quality roads and highly-developed transport modes. Ratios of this KPI cluster aim to assess the functionality of the integrated public transport system in terms of its availability for citizens, the public transport density and convenience of switching from one mode to another for citizens.

The second group of KPI classes aims to be used for evaluating the performance goal such as "Maintenance of green environment". Despite the fact that nowadays green environment presents a huge and broad topic, the experience of Copenhagen, Hong Kong, Vienna and Innopolis allowed to divide this group of indicators into three classes based on their common domains. First of all, the big part of the green strategy is waste recycling that demands efforts of the city administration, availability of city infrastructures and also the citizens culture and habits to recycle the household waste.

Moreover, the main reason for air pollution is the huge amount of emissions from the city transport. Replacing gasoline cars with electrical vehicles can solve this environmental problem and reduce the overall level of air pollution. CO_2-free transport modes such as cycling can become one of the alternatives to get closer to the green city. Furthermore, a higher number of electrical cars is also able to decrease CO_2-emissions into the atmosphere.

Besides decreasing water pollution, the rational use of water resources plays one of the key roles in the green and eco-friendly environment of the city. Like the energy consumption case, the solution to this problem also depends both on city managers and citizens. The eco-friendly usage can be calculated by means of KPIs such as daily water losses in liters per capita and the bacteria level in harbor.

One of the most important functions of smart cities is connected with enhancing the quality of citizens living as citizens are considered to be the major stakeholders of any urban settlement. For the interest of citizens, the quality of public services is very important. That includes the level of education with availability of schools, colleges, universities and the wide range of educational programmes provided. Moreover, the level of health care services as one of

the public services reflects the level of city smartness and advancement so the access to basic health care services is very important to evaluate. Also, the higher quality of citizens' life depends not only on physical facilities, but also on citizens' psychological state. This case reflects the importance of gender equality and higher safety of living conditions.

All the KPIs that can be used to evaluate the degree of ICT innovations implementation in various city areas are divided into four KPI classes. These classes include development of ICT talents (f. e., a number of local graduates from ICT programmes; intensity of university and ICT industry collaboration in terms of a number of contracts and agreements), density of electronic devices around the city area (f. e., a number of connected electronic sensors), city attractiveness for top international researchers, professors and students from science research and technical universities, and also a volume of investments in R&D projects (f. e., foreign investments in €; investments from local government in €).

Supporting businesses and enterprises in the context of smart city involves the intense use of different ICT instruments provided by the city government to enhance the easier collaboration and communication between both business and city management sides. This domain assumes availability of multi-sided platforms with participation of city management and cloud services. Moreover, it is important to support not just large-scaled corporations but also small and medium enterprises (SME) and startups in different industries through creating special governmental portals that aim to support such SMEs with legal, regulatory and other issues.

Development of smart government systems assumes the city administration being open to citizens in communication and sharing the information. For achieving this goal, the availability of multi-sided government services is very important to ensure the constant contact with businesses and individuals. These communication platforms can be presented through government mobile websites and mobile applications. To conclude, the use of ICT innovations is beneficial for the intense communication between city managers since it makes the public procedures less time-consuming.

The questionnaire as the final step of research methodology proves the results of expert interviews. Still, the additional KPIs relevant to smart city domains were suggested by respondents (Table 13). These new KPIs provided tend to complete all six smart city domains that were identified previously through the case study method.

Table 13

KPIs suggested from the questionnaire

Smart city domain	KPI	Measure
Green environment	Share of certified companies	% of companies
Resources and energy	Local food production Brownfield use Grey and rain water use	% of tonnes % of km^2 % of houses
Quality of citizens living	Net migration Unemployment rate Youth unemployment rate	Number % of citizens % of citizens
ICT innovations	Creative industry Innovation hubs in the city Density of connected electronic sensors distribution	% of people Number % of city area covered
Business and entrepreneurs	New business registered	Number/ per year
Smart government	Cross-departmental integration	Likert scale

To gain a deeper understanding of the smart city goals context the questions about frequency of reconsidering KPIs used to assess the specific goals were also asked during the survey (Figure 13). The questionnaire results demonstrate that dominant category within reconsideration of KPIs is "once every three years" (39%). The second most populous group is respondents who believe that smart city KPIs should be reconsidered once every two years (35%). All in all, the findings of reconsidering KPIs match with the results of reconsidering smart city goals and repeat the previous tendency as both actions present the parts of smart city strategy.

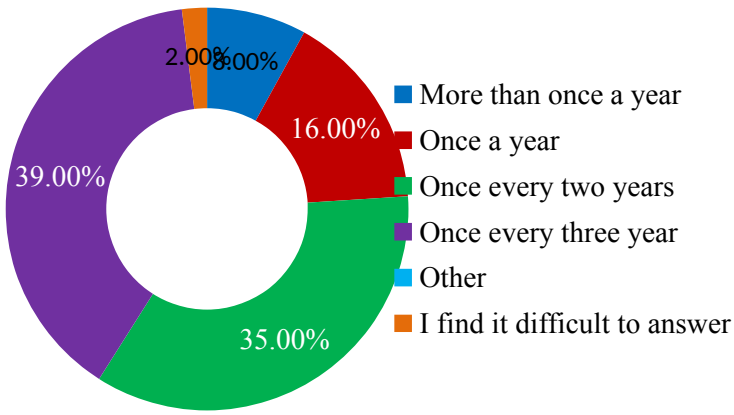

Figure 13 Frequency to ***reconsider KPIs*** that are used to assess goals

The question of recalculating KPIs is also one of the most important and arguable. The assumptions made previously based on responses of Copenhagen, Hong Kong, Vienna and Innopolis representatives suggest that in most cases the frequency of calculating and analyzing KPIs depends on the smart city domain and even on concrete smart projects, solutions and their peculiarities. On the other side, the more frequent KPI calculation alongside with continuous

evaluation provides a deeper understanding of the current status in smart city goals achievement. According to the questionnaire results the dominant group of answers about frequency of recalculating and analysis of KPIs that are used to assess smart city goals is "once a year" with the 49% of votes. The following response categories are "more than once a year" and "other" with 24% and 14% respectively (Figure 14). The comments of the "other" answers category suggests that the frequency to recalculate KPIs values depends on the smart city domain and specific city goal/ area that is going to be evaluated.

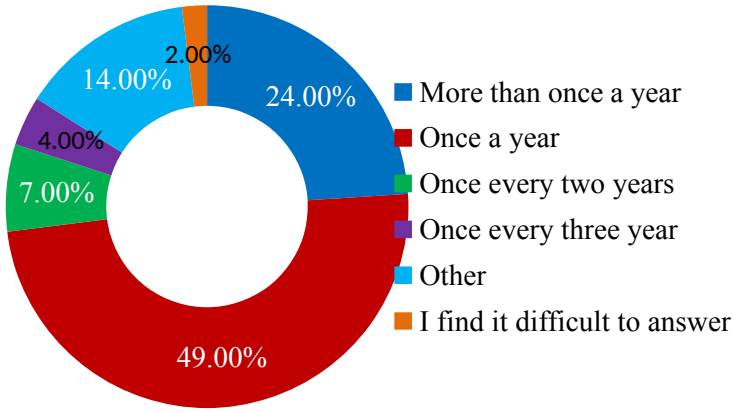

Figure 14 Frequency to ***recalculate KPIs*** that are used to assess goals

The detailed results gathered both from case studies and questionnaires are presented through the list of concrete KPIs to be used for different smart city domains (Appendix 4). All in all, each of the smart city domains is mapped with three or four KPI classes that include concrete KPIs to be used to assess the specific domain actions. KPIs from each class are presented with both qualitative and quantitative ratios that are all relevant to evaluate the concrete smart city goal. KPI classes contain from two to nine concrete KPIs. The total number of KPIs that can be used to assess six smart city domains is 96 with the highest number of KPIs for the "Resources and energy" domain. Moreover, from the total number of KPIs included into the final Performance Management Model the amount of qualitative indicators is 19, that demonstrates the dominance of quantitative ratios (comparing with previously identified performance management models for smart cities).

3.3. Managerial implications and recommendations

The major practical value of a five-level Performance Management Model suggested for smart cities is the mapping of specific performance goals of smart cities with both concrete qualitative and quantitative KPIs relevant for assessing each performance goal. The final Performance Management Model provided can be used in practice by both internal and external stakeholders of smart city that have different aims and reasons to use KPIs values of exact smart

city. Figure 16 presents the stakeholder groups that can be interested in the results of performance evaluation of the concrete smart city (Figure 15). The internal stakeholders include smart city managers and administration that control intelligent city activities and are responsible for realization and development of the smart city strategy and separate smart solutions. The group of external stakeholders includes businesses and individuals that can be interested in investments into specific smart city areas, solutions and projects and also city managers of other smart cities that have the opportunity to benchmark their own practice with external ones.

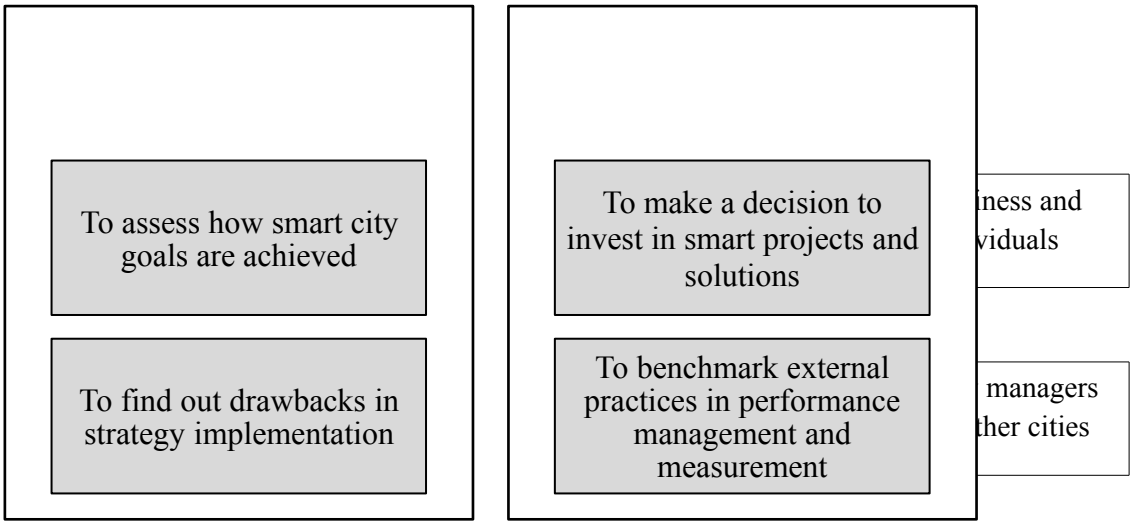

Figure 15 Managerial implications for different groups of smart city stakeholders

First of all, with the help of the suggested framework city managers are able to measure how smart city goals have been achieved during the certain period of time and also assess the progress of the work done. However, it is important to remember that performance management assumes not just measuring specific ratios. The results of such analysis are used in order to find the ways for further improvement of the efficiency and effectiveness of the existing programs (Tantardini and Kroll, 2015).

It also means that continuous monitoring and detailed analysis of a set of concrete KPIs values can become the basis to summarize and make some conclusions about some drawbacks in strategy implementation not evident from the very surface analysis.

Secondly, as it was already mentioned above the results and findings of the current research can be used not only by city managers but also by the external stakeholders. In general, the group of external stakeholders that can be interested in performance of the specific smart city includes companies, entrepreneurs, individuals and city managers of others smart cities that already exist or just start implementing their smart strategy. For example, the results of performance analysis of smart city can become the basis for the investment decision made by businesses and individuals if they would like to support specific smart city projects or solutions.

From this perspective, the more successful the specific project is, the more it will be attractive for investors to be included in their portfolio.

Moreover, external stakeholders such as representatives of other smart cities can be interested in the results of current research. It is useful to benchmark different practices in performance management and measurement as it gives the opportinity to use some valuable ideas and KPIs that are relevant for another smart city.

The theoretical contribution of current research is presented with the range of theoretical values added. First of all, the common components of smart city definitions are identified through the comparison of several scientific sources that also provided the possibility to construct the smart city definition to be used for current research. Besides, case studies on smart cities of Copenhagen, Hong Kong, Vienna and Innopolis were created based on the expert interviews with the representatives of smart cities and on documents and reports with the relevant information about smart city strategies implementation of Copenhagen, Hong Kong, Vienna and Innopolis available. Finally, based on the five-level Performance Management Model for R&D departments the Performance Management Model for smart cities that maps six smart city domains with concrete KPIs was provided.

The five-level Performance Management Model suggested as a final outcome of current research gives the opportunity to provide the set of recommendations for smart city managers. The recommendations are based on the structure of the final model itself and also on its semantic content.

One of the key milestones in successful realization and the smart city strategy implementation is setting a clear range of performance goals for different city areas that will make the process of performance management much easier in the future. Moreover, the performance goals should result from the smart city long-term goals and do not contradict with the smart city strategy, mission and vision. That follows from the link between the second and the third levels of a five-level model that present smart city goals and performance goals respectively. The very first step of the performance management process is planning and goals setting.

Moreover, it is better to divide concrete qualitative and quantitative KPIs into different clusters for a more detailed further analysis and an easier control process. These clusters should be relevant for concrete city goals in order to make the performance measurement process more complete. In its turn, this recommendation is based on the link between the third and the forth levels of final performance management and measurement model that are presented as performance goals and KPIs classes respectively.

Furthermore, performance management should be considered by the smart city administration as a continuous process. From one side, it can make the overall assessment process more time and efforts consuming as the data to be collected requires time and staff to be involved in this performance management process. From the other side, that leads to higher benefits for the smart city administration as the earlier the problems are found out the less costly it will be for city managers to eliminate them and reduce the negative effect of various circumstances.

3.4. Summary of chapter III

The final chapter of current master thesis presents the empirical results of the research through creating a five-level Performance Management Model for smart cities based on the case studies of Copenhagen, Vienna, Hong Kong and Innopolis and also the results of the questionnaire. So the sample for the case study includes three smart cities from European and Asian regions while the sample for the questionnaire includes more than 100 representatives from both international and Russian IT companies and research universities.

There are six smart city domains and also KPI classes that are mapped with concrete performance goals. The six domains include green environment, resources and energy, quality of citizens living, ICT innovations, business and entrepreneurs, and smart government. Each smart city domain is mapped with three or four KPI classes depending on the nature of the domain. The single KPI class includes from two to nine concrete key performance indicators that are relevant to the specific smart city goal.

Furthermore, the survey findings proved the importance of all the smart city domains provided. Moreover, some additional concrete KPIs are suggested that complete all six smart city domains provided from the case study results. It was also found from the questionnaire results that the frequency to analyze KPIs depends on goal specifics and city areas.

Based on the final results of current research the range of recommendations for smart city managers was provided. One of the most important points is connected with setting clear goals to be achieved within the certain period of time. These goals can be divided between city committees that makes the process of performance management much easier.

One more recommendation is based on the key advantage of the final model suggested that propose to divide concrete qualitative and quantitative KPIs into separate classes according to their domains and map these classes with relevant smart city goals. Moreover, performance management should have the constant basis that helps to find out problems and ways to solve them in time.

All in all, the final Performance Management Model provided can be used in practice by both internal and external stakeholders of smart city. Based on the KPIs values city managers are able to measure how smart city goals have been achieved. Furthermore, the analysis of KPIs calculated helps to find out drawbacks in strategy implementation.

Moreover, the results of performance analysis of smart city can become the basis for the investment decision made by businesses and individuals that are willing to support specific smart city projects or solutions in form of sponsorship or to gain profit.

One more external stakeholder side that can use the research results are city managers of other smart cities. They can be interested in benchmarking their own practice of smart city strategy implementation with the external practice in performance management and measurement while using some valuable ideas and KPIs that are relevant for their smart city and suitable for their smart city peculiarities.

CONCLUSIONS

In both developing and developed countries cities are considered to be the key elements of the social and economic development. According to the United Nations study, more than 60% of the total world population will live in cities by 2050 (United Nations, 2014). The intense population growth became the reason of urban problems such as traffic congestion, environment pollution, overconsumption of natural resources, and others. For nowadays, the smart city initiative is one of the most effective ways to solve various urban problems. However, as the phenomenon of smart city is relatively new there is still a lack of instruments that can be used to measure its performance.

Considering the lack of performance management systems to be used for smart cities the goal of current master thesis was set as creating the model with KPIs that can be used to assess the performance of smart cities. In order to achieve this goal, the range of research questions were also set. First of all, it was necessary to find out if any common practices for performance management of smart cities exist. Secondly, if a holistic performance management model can be provided based on the practices? And, finally, can any recommendations be given based on the final model suggested?

The current master thesis includes in-depth literature review of the smart city concept comparing and analyzing different definitions of smart city and identifying common components as there is still no one common definition for smart city. The practical experience of smart city strategies implementation in Europe, Asia and Russia was analyzed. However, as the practice of smart city strategy implementation is still not so widely spread all over the world there is a lack of instruments to be used for performance evaluation of smart city.

The literature review of existing performance management approaches for smart cities helped to find out the research gap as the current models include only qualitative indicators and do not make a clear connection between smart city goals/domains and KPIs to assess the relevant goals. Considering the drawbacks of existing performance management approaches for smart cities the five-level Performance Management Model was suggested to be used for performance evaluation of smart cities. The framework used to create the final Performance Management Model for smart cities was the five-level Performance Management Model provided previously for R&D departments of ICT companies (Samsonowa, 2012). This Model was chosen due to its main advantage which is mapping performance goals and relevant KPI classes. The smart city itself can be observed as the organizational unit as the performance management process for various units can be quite identical.

The model was constructed based on the case studies of Copenhagen, Hong Kong, Vienna and Innopolis, and also on the results of questionnaires with representatives of Russian and international IT companies and research universities. The key advantage of the final model suggested is mapping smart city domains with KPI classes that are relevant to assess specific goals. There are both qualitative and quantitative KPIs presented for each smart city domain.

The very first level represents the country level as every government sets its own goals in order to develop steadily, protect rights of citizens and be politically and economically stable. The second level explains smart city goals and its overall strategy as smart cities represent the part of the country and also the specific city has its own goals and objectives to be reached. The Activity level contains six smart city domains that reflect smart city goals and functions distributed usually among different city committees. These smart city domains include "Green environment", "Resources and energy", "Quality of citizens living", "ICT innovations", "Business and entrepreneurs", and "Smart government". The last two levels present the performance measurement system and contain KPI classes with concrete KPIs inside each class. Each domain is mapped with three or four KPI classes and includes both qualitative and quantitative KPIs. All in all, 96 concrete key performance indicators are presented to be used for performance evaluation of smart city.

In order to finalize the results of current research and also to prove that the preliminary goal was achieved the explicit answers to research questions are provided below.

RQ 1 – What is the common practice in regard to performance management of smart cities? Are there common smart city goals, and are there common key performance indicators (KPIs) to assess performance?

The smart cities that are successful in implementation and realization of the smart city strategy have practices regarding the performance management of smart city. In spite on the fact that the strategy and city goals can be different and quite individual for the separate smart city the domains to achieve the goals are similar for different smart city practices. Based on the case studies of Copenhagen, Vienna, Hong Kong and Innopolis smart cities six key smart city domains were identified that include green environment, resources and energy, quality of citizens living, ICT innovations, business and entrepreneurs, and smart government.

Despite the fact that smart cities in practice can be similar in city domains and smart city characteristics, performance measurement systems differ from each other. KPIs are divided into classes based on their domains while concrete KPIs to be used for performance evaluation of smart city are different.

RQ 2 – Is there a generic performance management approach to describe the common practice of performance management of smart cities? How are goals and KPIs reflected in this approach?

During the literature review on performance management of smart cities only two examples of performance management approaches were found out. However, the key disadvantages of existing approaches used for performance evaluation of smart cities are the lack of quantitative KPIs and also the lack of clear connection between smart city goals and exact KPIs to assess these goals.

RQ 3 – Can the holistic performance management model be provided based on the practices of real smart cities?

The analysis of smart city practical experience provided understanding that different smart city practices can be similar in their domains to make the city "smarter" in spite of their economic, political and cultural peculiarities. These six domains defined are closely correlated to the city areas. So based on the similarities of smart city strategy implementation the holistic performance management model can be suggested to be used by various smart cities for performance evaluation.

RQ 4 – Can there any recommendation be derived from the suggested approach to advise on the implementation and further development of a performance management and measurement model in smart city?

As the final five-level Performance Management Model is built considering the practical experience of different smart city strategies implementation, smart cities experience in performance management and the personal opinion and experience of representatives of IT companies and research universities, the set of recommendations was provided. These recommendations can be used by smart city managers to improve the existing performance management system or develop the new one.

Moreover, the results of current research can be considered as a platform for future research. First of all, in the literature review part some practical examples of implementations and realization of the smart city strategy both worldwide and in Russia were provided. However, the final Performance Management Model is suggested based on the data collected from expert interviews in European and Asian smart cities and on the experience and personal opinions of representatives of ICT companies and computer science universities that are involved in separate smart solution projects of different domains.

Finally, it is also important to remember that the final five-level Performance Management Model provided can be adapted by any smart city initiatives with fulfilling the set of KPIs based on its smart city domains and also economic, political and cultural peculiarities.

APPENDICES

Appendix 1. Interview Guideline

Table 14

Questions for the expert interviews with smart city representatives

Question Block	Questions
General Info	Smart city name
	Job title of respondent
	Department/ Committee
	Area of activities
	Structure of smart city administration
Smart city goals	Can you name key smart city goals?
	Do different Committees have their own goals?
	How the goal achievement is measured?
Do you have performance management tools?	Yes/ No/ Why?
	Short description
	Did you create the system by yourself or is it other smart cities experience?
	Problems/ Disadvantages?
	Number of KPIs? What are they?
	Do you make difference between short- and long-term KPIs?
	How often do you collect and analyze KPIs?
Are the KPIs of Committee derived from smart city goals?	How often do you reconsider the KPIs?
	How often do you synchronize KPIs with goals?
	How do you derive KPI of Committee from the overall smart city KPIs?
	What is the reason for measuring the performance?

Appendix 2. Case studies

Appendix 2.1. Case study: City of Copenhagen

City of Copenhagen Profile

Copenhagen is the capital and the biggest city of Denmark in terms of population. As the capital Copenhagen also plays the role of political, economical and cultural center of Denmark. Since the 21st century, Copenhagen has undergone the strong urban development, facilitated by investment in its infrastructure and institutions. Moreover, with Copenhagen Stock Exchange the city is known as one of the major financial centers of Northern Europe. However, being one of the most progressive and attractive cities in both Denmark and Europe leads to the intense growth of urban population with approximately 1,000 new inhabitants every month. To prevent the negative circumstances of overpopulation in Copenhagen the city administration has already launched smart city solutions. Alongside with recent developments in the pharmaceutical industry and the city service sector, the number of initiatives in clean technology was launched. These initiatives aim to support the city's goal to become carbon-neutral by 2025 (Københavns Kommune, 2016).

The strategy of becoming green, healthier and smarter city is accompanied with both smart initiatives and rewards for successfully implemented projects. According to Siemens Green Index in 2009 Copenhagen was identified as the greenest major city in Europe among all other 30 European cities (Siemens.com, 2016). In 2014 Copenhagen was named "European Green Capital" by the European Commission (Ec.europa.eu, 2016), and "World's Healthiest City" by CNN (Stateofgreen.com, 2016).

Smart City Initiative Profile

The Copenhagen Smart city initiative that is under control of the city administration attracts citizens to solve problems and develop new ideas or decisions to make their city "smarter". Moreover, the Copenhagen Solutions Lab (CSL) was founded in 2014 with the focus to implement smart city projects and innovations in close collaboration with knowledge institutions and companies as well as citizens (Cphsolutionslab.dk, 2016).

CSL represents the City of Copenhagen's incubator for various smart city initiatives. To make the process of creating and launching smart city ideas and projects more efficiently CSL works in close collaboration with all the departments of the Copenhagen administration. Working focus points within the Lab include reduction of carbon emissions, new various information technology solutions, implementation of sensors that are able to provide citizens

with real time data and information on current events, situations and activities in the city (Cphsolutionslab.dk, 2016).

Smart City Goals and Domains

The key perspective of Copenhagen is to make the City more effective and successful in terms of energy consumption. By 2025 Copenhagen wants to become the world's first carbon neutral capital. In 2009 the City administration developed and adopted the Climate plan that explains steps of how to make the green, smart and carbon neutral city. The CPH 2025 Climate plan includes objectives, efforts and initiatives adopted by the City Council that must be launched in order to achieve the goal of carbon neutrality.

According to the City strategy, Copenhagen aims to become the world's first carbon neutral capital by 2025, while the city's universities and businesses will lead the development of green solutions generating sustainable green growth and employment.

Main domains of Copenhagen considered for achieving the smart city goal of carbon neutrality are mobility (smart and eco-friendly transport systems), water (effective and smart water consumption), energy and resources (effective use of existing resources while reducing wastes), and strategy (urban planning and infrastructure) (Table 15).

Table 15

Smart city of Copenhagen domains

Domains	Description
Mobility	Smart and eco-friendly transport systems
Water	Effective and smart water consumption
Energy and Resources	Effective use of existing resources while reducing wastes
Strategy	Urban planning and infrastructure

Smart City KPIs

All the key performance indicators (KPIs) used to assess performance are divided into 10 KPI classes with the number of concrete KPIs inside each class ranging from three to six (Table 16).

Table 16

The list of KPIs used by smart city of Copenhagen

KPI class	Concrete KPI	Measure
Building	Attractiveness of urban areas for citizens	Likert scale
	Health and quality of life	Likert scale
	Pay back period of investments in energy savings	Number of years
Cooling	CO_2 emissions with the use of district cooling	Tonnes/ per year
	Electricity consumption with the use of district cooling per single citizen	Watt/ per year
	Sulphur dioxide emissions with the use of district cooling	Tonnes/ per year

	Nitrogen oxide emissions with the use of district cooling	Tonnes/ per year
	Expenditure on energy imports	€/ per year
Cycling	Quantity of cycling Copenhageners and commuters	Number
	Net social gain for every km travelled by bike instead of car	€/ per km cycled
	Health care costs saved for single citizen	€/ per km cycled
	Distance travelled in bicycle	km/ per workday
	Bicycle parking facilities	Number
Harbour	Bacteria level	Biochemical oxygen demand (BOD)
	Diversity of flora and fauna	Number of different species
	Proximity of citizens to blue recreational space	Likert scale
Heating	Heating provided from the district heating grid	% of total heating
	Energy generated from waste	% of total energy generated
	Energy generated from biomass	% of total energy generated
	Heating costs per single consumer	€/ per year
Integrated public transport	Quantity of car trips	Number
	CO_2 emissions	Tonnes/ per year
	Quality of life from convenient public transport	Likert scale
	Time saved due to less traffic congestion	Hours/ per day
	Convenience of transfer between each mode	Likert scale
Urban planning	Access to regional green areas by metro improves the quality of life	Likert scale
	Space for sports and social activities	km^2
	Attractiveness for residents, businesses and tourists	Likert scale
Waste recycling	Waste volume recycled	Tonnes/ per year
	Waste volume incinerated	Tonnes/ per year
	Household recycling level	% of total household waste
	Greenhouse gas emissions from incineration	m^3
Water usage	Daily water consumption	Liters/ per capita
	Daily water losses	Liters/ per capita
	Production costs of local businesses through greater water efficiency	€/ per year
	Demand for bottled water	Liters/ per capita
Wind power	Quantity of wind turbines	Number
	Electricity production from wind power	% of total electricity production
	Sulphur dioxide emissions	Tonnes/ per year
	Nitrogen oxide emissions	Tonnes/ per year
	CO_2 emissions	Tonnes/ per year

Table 17

Map of smart city of Copenhagen domains and KPIs

	Smart city domains			
KPI classes	**Mobility**	**Water**	**Energy and resources**	**Strategy**
Building			1. Attractiveness of urban areas for citizens 2. Health and quality of life 3. Pay back period of investments in energy savings	
Cooling			1. CO_2 emissions with the use of district cooling 2. Electricity consumption with the use of district cooling per single citizen 3. Sulphur dioxide emissions with the use of district cooling 4. Nitrogen oxide emissions with the use of district cooling 5. Expenditure on energy imports	

Cycling	1. Quantity of cycling Copenhageners and commuters 2. Health expenses saved by cycling 3. Net social gain for every km travelled by bike instead of car 4. Health care costs saved for single citizen 5. Distance travelled in bicycle 6. Bicycle parking facilities			
Harbour		1. Bacteria level 2. Diversity of flora and fauna 3. Proximity of citizens to blue recreational space		
Heating			1. Heating provided from the district heating grid 2. Energy generated from waste 3. Energy generated from biomass 4. Heating costs per single consumer	

Integrated public transport	1. Quantity of car trips 2. CO_2 emissions 3. Quality of life from convenient public transport 4. Time saved due to less traffic congestion 5. Convenience of transfer between each mode			
Urban planning				1. Access to regional green areas by metro improves the quality of life 2. Space for sports and social activities 3. Attractiveness for residents, businesses and tourists
Waste recycling			1. Waste volume recycled 2. Waste volume incinerated 3. Household recycling level 4. Greenhouse gas emissions from incineration	
Water usage		1. Daily water consumption 2. Daily water losses 3. Energy consumption from water services 4. Production costs of local businesses through greater water efficiency 5. Demand for bottled water		

Wind power			1. Quantity of wind turbines 2. Electricity production from wind power 3. Sulphur dioxide emissions 4. Nitrogen oxide emissions 5. CO_2 emissions	

Conclusions

Copenhagen as any political, economical and social center in Europe faces a lot of problems related to increased population, resources consumption and workload on the existing infrastructure. Copenhagen was one of the pioneers in Europe that realized the necessity of smart city development to optimize city processes and increase the welfare of citizens. During the last years there have been several complex smart city initiatives being introduced in Copenhagen what makes it very urgent to find the ways of how to manage and measure smart city development.

According to the City Strategy, the Copenhagen's aim with the highest priority is to become the first carbon capital in the world by 2025. The interrelated goals that follow from this vision break down to four directions:

1. Introduction of smart transport systems *(mobility);*
2. Effective water consumption *(water);*
3. Effective use of resources with minimized wastes *(energy and resources);*
4. Urban planning and infrastructure *(strategy).*

The case study of Copenhagen allowed mapping these goals with specific city areas and KPIs that enable smart city stakeholders to manage and measure the performance of Copenhagen as a smart city.

The case study also showed that Copenhagen uses specific KPIs to measure the achievement of each goal of smart city development. The scope of these KPIs is quite large what illustrates that the city regards the effective management and performance of smart city development as a complex task. These KPIs include both qualitative and quantitative indicators to make the process of performance management and measurement more effective and unbiased. Quantitative KPIs include such indicators as number of new facilities and places, the amount of consumed resources and the amount of expenses. Qualitative KPIs relate mainly to the level of the citizens satisfaction from the use of smart city services and facilities and the level of attractiveness of specific smart city initiatives.

Despite the fact that Copenhagen succeeded in developing the set of KPIs to manage and measure the smart city performance, not every goal of smart city development is mapped with target smart city areas and appropriate KPIs. This can result in the problem of poor interrelation of goals that were derived from the primary aim of Copenhagen as a smart city. Finally, for each goal city used the unbalanced number of KPIs. The main gap is identified with the goal of the strategic level – effective urban planning and infrastructure.

Appendix 2.2. Case study: Hong Kong

City of Hong Kong Profile

Hong Kong is a special administrative region of the Republic of China situated on the southern coast of the country. It is one of the leading financial centers not only in Asia but all over the world. There are more than 7 million citizens of various nationalities living in Hong Kong at present that makes this city one of the world's most densely populated metropolises. Limited land space resulted in the dense infrastructure and made the territory of Hong Kong a centre of modern architecture. Hong Kong also has a highly developed public transportation network that relies on mass transit by road or rail services.

However, being in the list of the top five of countries and territories by the population density Hong Kong encounters the range of urban problems (Data.worldbank.org, 2016).

In 1998 the Digital 21 Strategy was launched as one of the first steps of Hong Kong in the overall development of Information and Communication Technologies (ICT). Later the International Institute for Management Development twice considered Hong Kong as the first in technological infrastructure development in 2012 and 2013 (Gov.hk, 2016).

Smart City Initiative Profile

Invotech is a non-profit initiative launched in 2013 and dedicated to promoting and supporting positive changes in Hong Kong through innovation and technology. One of the Invotech goals is to engage individuals, entrepreneurs, corporations, associations, academies and the government to leverage their collective efforts in order to improve Hong Kong. Invotech seeks to create and sustain new ecosystems that help Hong Kong evolve and become more innovative.

The Smart Hong Kong initiative of Invotech is designed to bring together likeminded people to achieve a sustainably prosperous future. Finding the balance in the ecosystem means reaching the consensus, a common understanding of what "mutually beneficial" really means. A free sharing of ideas, knowledge and dreams among all the stakeholders in the society is the only way forward (Invotech, 2016).

Smart City Goals and Domains

The central aspects of the Smart Hong Kong initiative include environment, public services, citizens' empowerment, business initiation and ICT industry support (Table 18).

Table 18

Smart city of Hong Kong domains

Domains	Description
Environment	Sustainable development without degrading ecology
Public services	Developing of e-government services that offer convenient and efficient option for public while they are dealing with the Government
Empowering citizens	Enhancing basic capabilities of citizens to operate in an ICT-rich environment
Igniting business	Boosting operational efficiency and business opportunities
ICT industry support	Growing local ICT industry as a sheer enabler supporting other industries while also facilitating ICT sector to consolidate as a major economic contributor

Smart City KPIs

All the key performance indicators (KPIs) used to assess performance by the smart city of Hong Kong are divided into 11 KPI classes with the number of concrete KPIs inside each class ranging from one to five (Table 19).

Table 19

The list of KPIs used by smart city of Hong Kong

KPI class	Concrete KPI	Measure
City-wide Wi-Fi	Quantity of Wi-Fi hotspots	Number
	Quantity of locations with Wi-Fi hotspots	Number
	Internet connection speed	MB/ sec
	Wi-Fi penetration rate	m^2
Digital identity	Quantity of active digital certificate users (individual)	Number
	User-friendly digital certificates	Likert scale
e-Learning	Availability of online learning resources	Likert scale
	Quantity of Wi-Fi hotspots at schools	Number
	Availability of ICT education in school curriculum	% of schools providing ICT education
Establishing innovative platforms	Quantity of patents granted to the six local territory institutions engaged in technological research and development	Number
	Quantity of economically active spin-off companies	Number
	Income generated from intellectual property rights	€/ per year
ICT Talent development	Quantity of local graduates from ICT programmes	Number/ per year
	Intensity of university-ICT industry collaboration	Number of partner agreements/ per year
	Rewards for ICT innovations	Number/ per year
Infrastructure	Quantity of connected sensors in warehouse management	Number
	Quantity of connected sensors in luggage handling	Number
	Quantity of connected sensors in trade and logistics	Number

	Quantity of connected sensors in livestock control	Number
Multi-platform Government services	Quantity of government mobile websites	Number
	Quantity of government mobile apps	Number
Paperless solutions	Costs saved due to the less paper usage	€/ per year
	Storage space saved	m^2
	Information sharing intensity	Likert scale
SME Cloud services	Quantity of cloud services for SMEs	Number
	Intensity of mobile apps use	Likert scale
Startup ecosystem	Availability of online portal to serve startups	Likert scale
Waste recycling	Waste generation per capita	kg/ per day
	Quantity of waste separation bins in public spaces	Number
	Quantity of waste separation bins in commercial and industrial buildings	Number
	Percentage of population using recycling bins	% of total population
	Disposal of household garbage per capita	kg/ per day

Mapping goals and KPIs

Table 20

Map of smart city of Hong Kong domains and KPIs

	Smart city domains				
KPI classes	**Environment**	**Public services**	**Empowering citizens**	**Igniting business**	**ICT industry support**
City-wide Wi-Fi			1. Quantity of Wi-Fi hotspots 2. Quantity of locations with Wi-Fi hotspots 3. Internet connection speed 4. Wi-Fi penetration rate		
Digital identity			1. Quantity of active digital certificate users (individual) 2. User-friendly digital certificates		
e-Learning			1. Availability of online learning resources 2. Quantity of Wi-Fi hotspots at schools 3. Availability of ICT education in school curriculum		

Establishing innovative platforms				1. Quantity of patents granted to the six local territory institutions engaged in technological research and development 2. Quantity of economically active spin-off companies 3. Income generated from intellectual property rights	
ICT Talent development					1. Quantity of local graduates from ICT programmes 2. Intensity of university-ICT industry collaboration 3. Rewards for ICT innovations

Infrastructure		1. Quantity of connected sensors in warehouse management 2. Quantity of connected sensors in luggage handling 3. Quantity of connected sensors in trade and logistics 4. Quantity of connected sensors in livestock control			
Multi-platform Government services		1. Quantity of government mobile websites 2. Quantity of government mobile apps			
Paperless solutions		1. Costs saved due to the less paper usage 2. Storage space saved 3. Information sharing intensity			
SME Cloud services				1. Quantity of cloud services for SMEs 2. Intensity of mobile apps use	
Startup ecosystem					***1.*** Availability of online portal to serve startups

Waste recycling	1. Waste generation per capita 2. Quantity of waste separation bins in public spaces 3. Quantity of waste separation bins in commercial and industrial buildings 4. Percentage of population using recycling bins 5. Disposal of household garbage per capita				

Conclusions

Hong Kong as one of the most rapidly developing cities in both China and all over the world and as one of the top five territories by population density tends to face the range of urban problems (Data.worldbank.org, 2016). Hong Kong actively promotes ICT development that aims to support various city areas thus enhancing the quality of citizens living and eliminating negative circumstances of urban problems. Latest technologies such as Cloud computing, Big data analytics, Internet of Things, Wireless and multi-platforms are going to be adopted in different sectors.

Moreover, Invotech as the Smart City initiative aims to create and implement smart projects and innovative ideas that enhance public services, support businesses, and improve the eco-environment and the quality of citizens' life in Hong Kong. The list of Hong Kong smart city domains and objectives includes the following ones:

1. Sustainable development without degrading the ecology *(environment)*;
2. Developing of e-government services that offer convenient and efficient options for public while dealing with the government *(public services)*;
3. Enhancing basic capabilities of citizens to operate in an ICT-enriched environment *(empowering citizens)*;
4. Boosting operational efficiency and business opportunities *(igniting business)*;
5. Growing the local ICT industry as an enabler for supporting other industries and also facilitating the ICT sector to consolidate as a major economic contributor *(ICT industry support)*.

In the context of the Digital 21 Strategy "Smarter Hong Kong, Smarter Living" theme specific methods and ratios to measure the performance of smart initiatives are provided. They are both qualitative (i.e., availability of online portals to serve startups, availability of online learning resources) and quantitative ones (i.e., waste generation per capita, quantity of government mobile websites, quantity of local graduates from ICT programmes) relevant to specific smart city domains of Hong Kong.

However, the number of KPIs that are used to assess the smart city performance is unbalanced for different smart city domains. Moreover, the biggest part of KPIs tends to evaluate how ICT serves various Hong Kong areas that can provide the limited picture about the performance of the smart city.

Appendix 2.3. Case study: City of Vienna

City of Vienna Profile

Vienna is the federal capital of Austria and also one of nine federal provinces of Austria located in the eastern part of the country. Population of Vienna amounts to 1.8 million people; together with suburbs reaches the level of 2.3 million (AUSTRIA, 2016). Thus, Vienna is the largest city by population in Austria, occupying the eleventh place among the largest cities in the European Union. Moreover, the City of Vienna also takes roles of the cultural, economic and political center of Austria.

Vienna is one of the most successful cities all over the world where the infrastructure, innovations and the quality of life are highly concerned (Mercer.com, 2016). That is why the government of Vienna took a decision to establish the new initiative named Smart City Wien with the goal to hold the current position and further develop the concept of "smart city". By 2014 the smart city of Vienna has already succeeded in becoming one of the six most successful European cities with smart city initiatives (European Parliament, 2014).

Smart City Initiative Profile

Smart City Wien is the initiative that was launched in 2011 under the control of Mayor Michael Häupl in the city of Vienna with long-term goals to improve the design and development of the federal capital. This initiative aims to cover all the areas of the city while making the life quality of its citizens much better. Various activities in the context of this smart city initiative relate to infrastructure, energy, mobility and other key areas of urban development (Smartcity.wien.gv.at, 2016).

Smart City Wien stands for "intelligent city" that assumes the deployment of innovative and intelligent solutions for citizens and also the sustainable, effective and responsible use of resources. As the Initiative touches all areas of city life it means that all municipal departments in collaboration with many science and business experts have contributed to the development of basic principles and objectives of Smart City Wien (Smart City Wien, 2014).

Smart City Goals and Domains

The key long-term objective of the Smart City Wien Initiative is to significantly reduce the resource consumption in Vienna while continuing to offer the high quality of living, safety and security for all citizens by 2050. The central aspects of the Smart City Wien Framework Strategy include resources, innovation and quality of living (Table 21).

Table 21

Smart city of Vienna domains

Domain	Description
Resources	Radical resource preservation
Innovation	Development and productive use of innovations/ new technologies
Quality of living	High and socially balanced quality of living

Smart City KPIs

Nowadays, there are no fixed KPIs that aim to measure Smart City Wien Framework strategy. While the City of Vienna is a part of such research projects as CityKeys (European research project) and Smart.Monitor (national research project) that deal with Smart City KPIs. All the KPIs provided below are suggested based on the analysis of Smart City Wien Framework Strategy targets and are going to be adapted in the future (Table 22). All the key performance indicators (KPIs) are divided into 10 KPI classes with the number of concrete KPIs inside each class ranging from two to five.

Table 22

The list of KPIs used by smart city of Vienna

KPI class	Concrete KPI	Measure
Buildings	Energy consumption of existing buildings for space heating/cooling/water heating	Watt/ per service
	Cost optimization	€/ per new structure
Economy	Purchasing power	GDP/ per capita
	Quantity of hearquarters of international companies	Number
	Quantity of new enterprises	persons/ year
	Direct investment flows	€/ year
	Technology-intensive products sales	% in the expert volume
Education	Quantity of whole-day and integrated schools	Number
	Quantity of high-quality childcare offerings	Number
	Educational level	% of citizens with higher education
Energy	Final energy consumption	Watt/ per capita
	Primary energy input	Watt/ per capita
	Renewable sources of energy	% of gross energy consumption
Environment	Share of green spaces	% of total city square
	Savings achieved by municipal waste management	tonnes of CO2 equivalents
Healthcare	Affordability of healthcare services	Likert scale
	Quantity and quality of their leisure time	Likert scale

Infrastructure	Openness of government	Likert scale
	Quantity of pilot projects with ICT enterprises are to serve as showcases for the city and its economy	Number
	Public space Wi-Fi coverage	% of m^2
Mobility	CO_2-free modes (walking and cycling)	% of total vehicles
	Motorised individual traffic (MIT)	% of total vehicles
	CO_2-free commercial traffic originating and terminating	% of total commercial traffic
Research, Technology and Innovation	Attractive research and innovation hub	Rating in Europe
	Quantity of research units of international corporations	Number
	Quantity of international top researchers	Number
	Quantity of international students	Number
Social inclusion	Safety of life conditions	Likert scale
	Attractiveness of housing environment	Likert scale
	Absence of gender superiority	Likert scale

Table 23

Map of smart city of Vienna domains and KPIs

	Smart city domains		
KPI classes	**Resources**	**Innovations**	**Quality of living**
Buildings	1. Energy consumption of existing buildings for space heating/ cooling/ water heating 2. Cost optimization		
Economy		1. Purchasing power 2. Quantity of hearquarters of international companies 3. Quantity of new enterprises 4. Direct investment flows 5. Technology-intensive products sales	
Education		1. Quantity of whole-day and integrated schools 2. Quantity of high-quality childcare offerings 3. Educational level	
Energy	1. Final energy consumption 2. Primary energy input 3. Renewable sources of energy		
Environment			1. Share of green spaces 2. Savings achieved by municipal waste management
Healthcare			1. Affordability of healthcare services 2. Quantity and quality of their leisure time

Infrastructure	1. Openness of government 2. Quantity of pilot projects with ICT enterprises are to serve as showcases for the city and its economy 3. Public space Wi-Fi coverage		
Mobility	1. CO_2-free modes (walking and cycling) 2. Motorised individual traffic (MIT) 3. CO_2-free commercial traffic originating and terminating 4. Energy consumption by passenger traffic		
Research, Technology and Innovation		1. Attractive research and innovation hub 2. Quantity of research units of international corporations 3. Quantity of international top researchers 4. Quantity of international students	
Social inclusion			1. Safety of life conditions 2. Attractiveness of housing environment 3. Absence of gender superiority

Conclusions

Being one of the most developed cities in Europe and the political and economical center of Austria, the City of Vienna faces the problem of overpopulation that leads to overconsumption of natural resources and environment pollution. The Smart City Wien initiative was launched in 2011 as a project that brings together all relevant fields of knowledge and involves all relevant stakeholders with the objective of solving current urban problems and continuously building on city's strengths. Nowadays, the City of Vienna is included in the list of the six most successful European cities with smart city initiatives based on the city activity in the context of country's priorities (European Parliament, 2014).

Furthermore, Vienna is one of the participants of CITYkeys projects founded in February, 2015 by the European Union HORIZON 2020 programme with the goal to develop KPIs and data collection procedures for monitoring of smart city solutions across European cities (Citykeys-project.eu, 2016).

Following the long-term goal of providing the high quality of living, safety and security for its citizens through reducing resource consumption by 2050, the smart city of Vienna identifies and follows three key domains that include:

1. Radical resource preservation *(resources)*;
2. Development through the effective and efficient use of innovations and new technologies *(innovations)*;
3. Maintenance of the high and socially balanced quality of citizens living *(quality of living)*.

In order to continuously track how the smart city plan performs and measure the level of goals achievement, the Smart City Wien Framework Strategy provides specific ways and means to reach the results and objectives set. Moreover, the range of specific KPIs is also suggested to assess how the smart city goals have been achieved.

The KPIs are divided into separate classes relevant to each single city domain. Every KPI class contains both qualitative and quantitative indicators that give the possibility to get the clearer understanding of the current picture of the smart city of Vienna. Qualitative KPIs mainly include ratios such as affordability of various public services for the citizens, their personal comfort and feeling of safety while staying and living in the City of Vienna (i.e., affordability of healthcare services, safety of life conditions, absence of gender superiority, etc.). Quantitative KPIs can be measured in certain numbers and contain such indicators as energy consumption, share of green spaces, public space Wi-Fi coverage and others.

Furthermore, in-depth analysis of current practice of smart city of Vienna in performance management provides possibility to suggest some recommendations for further improvement.

Firstly, the list of domains can still be completed with green environment and smart governance alongside with concrete KPIs to measure these objectives. Moreover, the KPI class such as "social inclusion" can be enhanced also with quantitative KPIs, since only qualitative ones make the assessment more subjective and incomplete.

Appendix 2.4. Case study: City of Innopolis

City of Innopolis Profile

Innopolis is a new built city founded in 2015 which is located on the territory of the Republic of Tatarstan. While the story of Innopolis starts from 2012 when the Prime Minister of the Russian Federation together with the President of the Republic of Tatarstan signed agreement for the construction of new intelligent city. The very first construction works already started in the end of year 2012 according with the master plan of architects from Singapore. Two years later the Innopolis urban settlement acquired the status of the city of Innopolis.

Nowadays, the city economy is based on the high-tech industries being. A unique safe environment alongside with modern residential infrastructure, broad opportunities for education and professional development have been created in Innopolis. The city provides multifamily houses and townhouses for its population, school of the Innopolis University, the kindergarten designed for 225 children, special economic zone for the companies-residents while the city infrastructure still will be expanded (Innopolis.ru, 2016).

Smart City Initiative Profile

The management of the city is under control of the Mayor's office. The Mayor of Innopolis was elected by the residents in December 2014. The responsibilities of the Mayor's Office of Innopolis are focused on creating a unique ecosystem with modern residential infrastructure, a safe environment both for working and living, and huge opportunities for education and professional development of Innopolis residents (Innopolis.ru, 2016).

Smart City Goals and Domains

The key goal of Innopolis is connected with creating one of the best platforms for the comfort work and living of IT-specialists while providing the sustainable development of the city. The smart city domains can be divided into five categories presented below (Table 24).

Table 24

Smart city of Innopolis domains

Domain	Description
Quality of citizens living	Providing wide opportunities for education and professional development
ICT development	Creating the platform for the comfort work and living of specialists in IT sphere
Environment	Safe environment for living and working
Infrastructure	Modern, high-quality residential infrastructure
Business support	Active attraction of business while providing them with advantages of being a resident company of Innopolis

Smart City KPIs

There are four KPI classes that is distinguished from the interview results with the Innopolis representative and also from the analysis of information available for free access. Each KPI class include from one to two concrete KPIs (Table 25).

Table 25

The list of KPIs used by smart city of Innopolis

KPI class	Concrete KPI	Measure
Education	Quantity of students	Number
Healthcare	Availability of healthcare services	Likert scale
Social comfort	Net migration Satisfaction of citizens	Number Likert scale
Business ecosystem	Quantity of companies employees Quantity of companies-residents	Number Number

Table 26

Map of smart city of Innopolis domains and KPIs

	Smart city domains				
KPI classes	**Quality of citizens living**	**ICT development**	**Environment**	**Infrastructure**	**Business support**
Education	1. Quantity of students				
Healthcare	1. Availability of healthcare services				
Social comfort	1. Net migration 2. Satisfaction of citizens				
Business ecosystem					1. Quantity of companies employees 2. Quantity of companies-residents

Conclusions

The city of Innopolis is planned as the intelligent city of new generation while being one of the first projects of smart city construction in Russian Federation. In general, Innopolis is considered to be a high-tech city and also a platform for the work and constant development of IT-specialists. All in all, the list of the Innopolis goals includes five key directions:

1. Providing wide opportunities for education and professional development *(quality of citizens living)*;
2. Creating the platform for the comfort work and living of specialists in IT sphere *(ICT development)*;
3. Maintenance of safe environment for living and working *(environment)*;
4. Providing modern, high-quality residential infrastructure for citizens *(infrastructure)*;
5. Active attraction of business while providing them with advantages of being a resident company of Innopolis *(business support)*.

The performance management of Innopolis is concentrated around the satisfaction of the city population while "happiness of the citizens" is mentioned as a key performance indicator being considered by the city managers. The instruments used by city administration to gather data about daily life of citizens, their problems, complaint or suggestions are Concierge Service 24/7 and Zendesk. Concierge Service 24/7 is a service created by Innopolis itself and aims to be the communication tool between city management and its population. Zendesk is adapted system that offers for its clients a wide range of customer service tools (Zendesk, 2016).

However, considering the fact that Innopolis as a smart city project was officially opened just in 2015, there is still a lack of high-qualified performance management model to be used for the goals evaluation. Not all the domains of Innopolis smart city is mapped with concrete KPIs that are used to evaluate city performance. Moreover, the list of KPIs existed is narrow and do not demonstrate the detailed picture of Innopolis functioning.

All in all, from the case of Innopolis and review of smart city context in Russia it is possible to summarize that the experience of intelligent cities in our country is not as rich as European and Asian smart cities have. The lack of KPIs to be used for performance evaluation of Innopolis is connected with the fact of recent foundation of the city. The positive tendencies present and are expressed in continuous communication with citizens while also gathering information about the work of various urban services.

Appendix 3. Online Questionnaire

Graduate School of Management
St. Petersburg State University

IPERF International Institute for Research Performance Management

"Performance Management & Measurement Model for Smart Cities"

Thank you for your participation in our survey.

Survey Profile and Objectives:

The current survey is a part of data collection for Master thesis that aims to create a model (holistic approach) for assessing performance of smart cities with both qualitative and quantitative ratios. The online questionnaire includes the following sections:

Section 1 collects information about goals that are set by smart cities and the importance and relevance of these goals for smart city development.

Section 2 collects information about specific dimensions of KPIs that can be used to assess performance of smart cities and the level of goals achievement.

To complete the questionnaire you will need approximately **20 minutes**. We also kindly ask you to complete the survey within **40 days**.

Thank you for your valuable input.

Respondent Profile:

Please fill the form below with your contact information. It gives us possibility to share with you the final results of our research.

Name:	
Company:	
Country:	
Email:	

Survey Approach:

All the responses from current survey will be analyzed and presented in a matrix form where exact KPIs map the smart city goals alongside with the importance of these single KPIs and goals for high smart city performance.

	Goal 1 (importance degree)	Goal 2 (importance degree)	Goal 3 (importance degree)	Goal N (importance degree)
KPI 1		+++		
KPI 2			++	
KPI 3			+	+++
KPI N		+	+	++

Section 1. Goals of smart cities

In this section you will be provided with goals that are most commonly used in smart cities strategies and plans for the further development. Please indicate the importance (priority) of these goals based on your personal opinion and experience. If the goal should not be assessed by smart city please match the first column. It is also possible to add the goal that you can feel is missed in the current list.

Goal	Should not be assessed	Should be assessed – ***low*** priority	Should be assessed – ***medium*** priority	Should be assessed – ***high*** priority
Using of resources and energy in effective way				
Maintenance of green environment				
Enhancing the quality of citizens living				
Implementation of ICT innovations in various city areas				
Supporting the business and enterprise				
Development of smart government systems				
Other goal:				
Other goal:				

How often smart city should ***reconsider its goals***? Please select the most appropriate answer from your point of view.

- More than once a year
- Once a year
- Once every two years
- Once every three year
- Other: _____
- I find it difficult to answer

Section 2. KPIs to assess the performance of smart city

In this section for those goals that were matched by you as important ones for smart cities we will provide set of possible KPIs. Please select more relevant ones to assess each goal achievement based on your own opinion and experience. If some KPIs are not relevant please select the first column.

Please select the KPIs from the table below that are relevant to the goal ***"Using of resources and energy in effective way"*** and identify their importance. It is also possible to add KPI that you can feel is missed in the current list.

Goal: "Using of resources and energy in effective way"				
KPIs assessing the…	Not relevant	Relevant – ***less*** important	Relevant – important	Relevant – ***very*** important
… effectiveness of energy usage (f. e., energy consumption in watt per capita; % of renewable sources of energy in gross energy consumption)				
… layout and convenience of buildings (f. e., attractiveness of urban areas for citizens; energy consumption of existing buildings for space heating/cooling/water heating in watt per service)				
… level of city infrastructure development (f. e., % of public space Wi-Fi coverage; space for sports and social activities in m^2)				
… layout of transport systems (f. e., time saved due to less traffic congestion for every single citizen per day; convenience of transfer between each mode)				
Other KPI:				
Other KPI:				

Please select the KPIs from the table below that are relevant to the goal ***"Maintenance of green environment"*** and identify their importance. It is also possible to add KPI that you can feel is missed in the current list.

Goal: "Maintenance of green environment"				
KPIs assessing the…	Not relevant	Relevant – ***less*** important	Relevant – important	Relevant – ***very*** important
… intensity of waste recycling (f. e., waste generation per capita in kg; greenhouse gas emissions from incineration in m^3)				
… volume of electrical (eco-friendly) vehicles (f. e., % of CO_2-free modes (walking and cycling) from total vehicles; % of electrical cars from total vehicles)				
… water eco-friendly usage (f. e., daily water losses in liters per capita; bacteria level in harbour)				
Other KPI:				
Other KPI:				

Please select the KPIs from the table below that are relevant to the goal ***"Enhancing the quality of citizens living"*** and identify their importance. It is also possible to add KPI that you can feel is missed in the current list.

Goal: "Enhancing the quality of citizens living"				
KPIs assessing the…	Not relevant	Relevant – ***less*** important	Relevant – important	Relevant – ***very*** important
… degree of social comfort (f. e., absence of gender superiority; safety of life conditions)				
… level of citizens' digital identity (f. e., number of active digital individual certificate users)				
… level of education				

(f. e., % of citizens with higher education; number of whole-day and integrated schools)				
… level of health care services (% of population with access to basic health care services)				
Other KPI:				
Other KPI:				

Please select the KPIs from the table below that are relevant to the goal ***"Implementation of ICT innovations in various city areas"*** and identify their importance. It is also possible to add KPI that you can feel is missed in the current list.

Goal: "Implementation of ICT innovations in various city areas"				
KPIs assessing the…	Not relevant	Relevant – ***less*** important	Relevant – important	Relevant – ***very*** important
… development of ICT talents (f. e., number of local graduates from ICT programmes; intensity of university-ICT industry collaboration in number of contracts and agreements)				
… density of electronic devices around the city area (f. e., number of connected electronic sensors)				
… attractiveness of city for foreign researchers (number of research units of international corporations; number of international top researchers and students)				
… volume of investments in R&D projects (f. e., foreign investments in €; investments from				

local government in €)				
Other KPI:				
Other KPI:				

Please select the KPIs from the table below that are relevant to the goal ***"Supporting the business and enterprise"*** and identify their importance. It is also possible to add KPI that you can feel is missed in the current list.

Goal: "Supporting the business and enterprise"				
KPIs assessing the…	Not relevant	Relevant – ***less*** important	Relevant – important	Relevant – ***very*** important
… intensity of innovative multi-sided platforms usage (f. e., number of platforms; number of business participants in platforms)				
… intensity of cloud services usage (f. e., number of cloud services for SMEs; intensity of mobile apps use)				
… startup ecosystem (f. e., availability of online portal to serve startups)				
Other KPI:				
Other KPI:				

Please select the KPIs from the table below that are relevant to the goal ***"Development of smart government systems"*** and identify their importance. It is also possible to add KPI that you can feel is missed in the current list.

Goal: "Development of smart government systems"				
KPIs assessing the…	Not relevant	Relevant – ***less*** important	Relevant – important	Relevant – ***very*** important
… degree of government openness (f. e., availability of free contacts with city administration)				
… availability of multi-platform government services (f. e., number of government mobile				

websites; number of government mobile apps)				
… number of connected sensors in public services (f. e., number of connected sensors in luggage handling; number of connected sensors in trade and logistics)				
Other KPI:				
Other KPI:				

How often smart city should ***reconsider KPIs*** that are used to assess goals? Please select the most appropriate answer from your point of view.

- More than once a year
- Once a year
- Once every two years
- Once every three year
- Other: _____
- I find it difficult to answer

How often smart city should ***recalculate*** KPIs that are used to assess goals? Please select the most appropriate answer from your point of view.

- More than once a year
- Once a year
- Once every two years
- Once every three year
- Other: _____
- I find it difficult to answer

Your responses have been submitted.

Thank you very much for your participation in our research.

Appendix 4. Map of smart city domains and concrete KPIs

Table 27

KPIs for "Green environment" domain

KPI class	Concrete KPIs	Measure
Intensity of waste recycling	1. Savings achieved by municipal waste management 2. Waste generation 3. Waste volume incinerated 4. Greenhouse gas emissions from incineration 5. Quantity of waste separation bins in public spaces 6. Quantity of waste separation bins in commercial and industrial buildings 7. Percentage of population using recycling bins 8. Disposal of household garbage	tonnes of CO_2 equivalents kg/ per capita tonnes m^3 Number Number % of total population kg/ per capita
Volume of electrical (eco-friendly) vehicles	1. CO_2-free modes (walking and cycling) 2. Motorised individual traffic (MIT) 3. CO_2-free commercial traffic originating and terminating	% of total vehicles % of total vehicles % of total commercial traffic
Water eco-friendly usage	1. Daily water losses 2. Daily water consumption 3. Demand for bottled water 4. Production costs of local business through greater water efficiency 5. Bacteria level in harbor 6. Diversity of flora and fauna 7. Proximity of citizens to blue recreational space	Liters/ per capita Liters/ per capita Liters/ per capita €/ per year Biochemical oxygen demand (BOD) Number of different species Likert scale

Table 28

KPIs for "Resources and energy" domain

KPI class	Concrete KPIs	Measure
Effectiveness of energy usage	1. Final energy consumption 2. Primary energy input 3. Renewable sources of energy 4. Local food production 5. Brownfield use 6. Grey and rain water use 7. Quantity of wind turbines 8. Electricity production from wind power 9. Electricity consumption with the use of district cooling	Watt/ per capita Watt/ per capita % of gross energy consumption % of tonnes % of km^2 % of houses Number % of total electricity production Watt/ per capita

Layout and convenience of buildings	1. Energy consumption of existing buildings for space heating/ cooling/ water heating 2. Cost optimization 3. Attractiveness of urban areas for citizens 4. Pay back period of investments in energy savings 5. Heating provided from the district heating grid 6. Heating energy generated from waste 7. Heating energy generated from biomass 8. Heating costs per single consumer	Watt/ per service €/ per new structure Likert scale Number of years % of total heating % of total energy generated % of total energy generated €/ per year
Level of city infrastructure development	1. Public space Wi-Fi coverage 2. Space for sports and social activities 3. Share of green spaces 4. Attractiveness for residents, businesses and tourists 5. Quantity of pilot projects with ICT enterprises are to serve as showcases for the city and its economy 5. Quantity of Wi-Fi hotspots 6. Quantity of locations with Wi-Fi hotspots 7. Internet connection speed 8. Wi-Fi penetration rate	% of m^2 m^2 % of total city square Likert scale Number Number Number MB/ sec m^2
Layout of transport systems	1. Time saved due to less traffic congestion 2. Convenience of transfer between each mode 3. Quantity of car trips 4. Quality of life from convenient public transport 5. Bicycle parking facilities	Hours/ per day for single citizen Likert scale Number Likert scale Number

Table 29

KPIs for "Quality of citizens living" domain

KPI class	Concrete KPIs	Measure
Degree of social comfort	1. Safety of life conditions 2. Attractiveness of housing environment 3. Absence of gender superiority 4. Net migration	Likert scale Likert scale Likert scale Number
Level of citizens' digital identity	1. Quantity of active digital individual certificate users 2. Availability of user-friendly digital certificates	Number Likert scale
Level of education	1. Quantity of whole-day and integrated schools	Number

	2. Quantity of high-quality childcare offerings 3. Educational level 4. Availability of online learning resources 5. Quantity of Wi-Fi hotspots at schools 6. Availability of ICT education in school curriculum	Number % of citizens with higher education Likert scale Number % of schools providing ICT education/ courses
Level of health care services	1. Affordability of healthcare services 2. Quantity and quality of their leisure time 3. Health care costs saved for single citizen	Likert scale Likert scale €

Table 30

KPIs for "ICT innovations" domain

KPI class	Concrete KPIs	Measure
Development of ICT talents	1. Quantity of local graduates from ICT programmes 2. Intensity of university-ICT industry collaboration 3. Rewards for ICT innovations 4. Creative industry participants	Number Number of partner agreements Number % of citizens
Density of electronic devices around the city area	1. Quantity of connected electronic sensors 2. Density of connected electronic sensors distribution	Number % of city area covered
Attractiveness of city for foreign researchers	1. Attractive research and innovation hub 2. Quantity of innovation hubs 3. Quantity of research units of international corporations 4. Quantity of international top researchers 5. Quantity of international students	Rating in country/ region/ world/ Likert scale Number Number Number Number
Volume of investments in R&D projects	1. Foreign investments 2. Investments from local government	€ €

Table 31

KPIs for "Business and entrepreneurs" domain

KPI class	Concrete KPIs	Measure
Intensity of innovative multi-sided platforms usage	1. Quantity of platforms 2. Quantity of business participants in platforms 3. Income generated from intellectual	Number Number €

	property rights 4. Quantity of economically active spin-off companies	 Number
Intensity of cloud services usage	1. Quantity of cloud services for SMEs 2. Intensity of mobile apps use	Number Likert scale
Startup and business ecosystem	1. New business registered 2. Direct investment flows 3. Quantity of headquarters of international companies 4. Availability of online portal to serve startups	Number € Number Likert scale

Table 32

KPIs for "Smart government" domain

KPI class	Concrete KPIs	Measure
Degree of government openness	1. Openness of government 2. Availability of free contacts with city administration 3. Cross-departmental integration 4. Information sharing intensity	Likert scale Likert scale Likert scale Likert scale
Availability of multi-platform government services	1. Quantity of government mobile websites 2. Quantity of government mobile apps 3. Costs saved due to the less paper usage 4. Storage space saved	Number Number € m^2
Number of connected sensors in public services	1. Quantity of connected sensors in warehouse management 2. Quantity of connected sensors in luggage handling 3. Quantity of connected sensors in trade and logistics 4. Quantity of connected sensors in livestock control	Number Number Number Number

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