Exploring the Nature of the Smart Cities Research Landscape

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Abstract As a research domain Smart Cities is only emerging. This is evident from the number of publications, books, and other scholarly articles on smart cities indexed in Google scholar and Elsevier's Scopus – an Abstract and Citation database. However, significant literature is available on related topics like intelligent city, digital city, and intelligent community based on search results research repositories such as Elsevier's Scopus, ACM Digital Library, and Google Scholar. This chapter maps the research work in the Smart Cities domain, based on the available scholarly publications. The aim is to synthesize an emerging understanding of the smart city concept, determine major research themes, types, and gaps in the current research landscape.

Keyword

Smart Cities, Intelligent Cities, Smart City Research, Research Mapping, Bibliometrics, Scientometrics

Cite as:

Ojo, A., Dzhusupova, Z., & Curry, E. (2015). Exploring the Nature of the Smart Cities Research Landscape. In R. Gil-Garcia, T. A. Pardo, & T. Nam (Eds.), *Smarter as the New Urban Agenda: A Comprehensive View of the 21st Century City*. Springer.

1 Introduction

The unprecedented level of urbanization and consequent growth in size and numbers of cities in different parts of the world present both challenges and opportunities. On the one hand, phenomenal growth (~10 fold) in urban population (from 250 million at the beginning of the 20th century, to 2.8 billion at the beginning of the 21st, with an expected rise to about 9 billion in 2050 (DiChristina, 2011)) challenges the traditional approaches to city management and urban lifestyle. For instance, the traditional approach to the management of transportation systems, water resources, waste, energy and natural environment in cities must be fundamentally rethought to cope in a sustainable manner with the pressure induced by growth in demand for these resources. On the other hand, given that cities constitute the social nexus (Ratti & Townsend, 2011) of the larger society providing the much needed intellectual and social capital for growth; and that bigger cities appear to be able to do more with less (Bettencourt & West, 2011), city growth may offer opportunities for more optimal city management and innovation. The collaborative creativity resulting from proximity and the constant interchange of ideas offered by cities has helped many cities, particularly in developing world to get out of poverty and integrate with the wider world economy (Glaeser, 2011)

In responding to challenges and opportunities of rapid urbanization and city growth, many governments at different levels – international, regional, national, and local; have initiated programs on Digital and Intelligent cities and lately Smart Cities. Digital, Intelligent, and Smart Cities are related concepts all involving the ICT-enabled transformation of the city, city management, as well as city inhabitants and actors. While the difference between the three concepts remain fuzzy (Hollands, 2008), differences have been noted in the changing focus and consequently the required capabilities in implementing initiatives associated with the three concepts.

Smart Cities as urban innovation and transformation initiatives aim to harness physical infrastructures, Information Communication Technologies (ICT), knowledge resources, and social infrastructure for economic regeneration, social cohesion, better city administration, and infrastructure management (Ojo, Curry, & Janowski, 2014). A distinguishing feature of the Smart City concept is the centrality of people or the welfare of its residents in its essence. Specifically, smart cities are concerned with the transformation of life and work of city inhabitants (Hollands, 2008). Smart Cities also focus on harnessing human collaboration for generating ideas which are considered the currency of the current age (Ratti & Townsend, 2011). This extended scope and focus on integration of different aspects of city –

administration, resource management, lifestyle, mobility, etc., makes the smart cities research more challenging and ambitious with respect to previous research on intelligent, and digital cities which focused primarily on the technology dimension (e.g. ICT infrastructure and services) and its transformational effect on other dimensions of the city.

While research in Urban Transformation is fairly mature with over three decades of work, research in Smart Cities, Intelligent Cities, and related areas is relatively new. However, given the close link between Smart Cities and major issues of interest to policymakers such as sustainability and technology-innovation in city-governments, research interest and outputs has been growing at a more rapid rate lately. Currently there are over 800 papers in Scopus with "Smart Cities" in their titles, abstract or keywords and over 7000 scholarly resources indexed in Google Scholar. We believe that this level of research outputs in the domain is sufficient to explore the emerging and future trends in Smart City research.

This chapter examines the Smart Cities research domain by analysing scholarly publications on the subject matter based on data available on Elsevier's Scopus database - the largest abstract and citation database of peer-reviewed literature: scientific journals, books and conference proceedings. The chapter is primarily targeted at researchers. Findings may also be of interest to practitioners to guide funding policies for research in the smart cities domain.

2 Conceptual Framework

This section provides the conceptual underpinning for the study definitions of core concepts of a Smart City. The term Smart City (or Smart Cities) has been adopted by different governments, consulting organizations (IBM, 2013) and research groups. Despite the wide use of the term, its meaning remains fuzzy (Caragliu, Bo, & Nijkamp, 2009; Nam & Pardo, 2011). Smart City according to (Giffinger et al., 2007) is "A City performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-decisive independent and aware citizens". This definition is based on the traditional regional and neo-classical theories of urban growth and development. In particular, the axes are based – respectively – on theories of regional competitiveness, transport and ICT economics, natural resources, human and social capital, quality of life, and participation of societies in cities. Based on Giffinger's definition, (Caragliu et al.,

2009) offers a similar definition of the concept as follows – "We believe a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance".

Smart Cities are expected to dramatically improve their citizens' quality of life, encourage business to invest, and create a sustainable urban environment (Vasseur & Dunkels, 2010). Interestingly, while the term *Smart City* literarily imply an outcome or result, most usage of the term consider it as an 'activator' of change through exploring relevant open innovation processes (Paskaleva, 2011). Other conceptualizations such as (Nam & Pardo, 2011) consider Smart City as urban innovation involving technological, organizational, and policy innovations. Finally, Smart City could be understood as a certain intellectual ability that addresses several innovative socio-technical and socio-economic aspects of growth (Zygiaris, 2012).

In (Hollands, 2008), three characteristic element of the Smart City concept were identified to include: 1) utilization of networked infrastructures to improve economic and political efficiency and enable social, cultural and urban development infrastructures including ICT; 2) business-led urban development; and 3) social and environmental sustainability. Social sustainability implies social cohesion and a sense of belonging, while environmental sustainability refers to the ecological and 'green' implications of urban growth and development. In (Komninos, 2011), the concept of spatial intelligence of cities is presented as a composite capability enabling communities within the city to harness the intellectual capital, institutions, and material infrastructure in dealing with problems and challenges. Spatial intelligence is composed of three types of intelligence: 1) the inventiveness, creativity and intellectual capital of the city; 2) the collective intelligence of the city's institutions and social capital; 3) the artificial intelligence of public and city-wide smart infrastructure, virtual environments, and intelligent agents. These three types of intelligence involve all dimensions of the city and maps to three types of spaces – physical, institutional, and digital. The "physical space" corresponds to the inventiveness and creativity of the city, the "institutional space" includes the social capital and collective intelligence of a city population, and "digital space" contains the artificial intelligence embedded into the physical environment, including public broadband communication infrastructure and digital technologies.

Focusing on the digital space, the following infrastructure networks for smart cities were identified in (Vasseur & Dunkels, 2010). Some of these

networks are related to transport, public safety and security, public services, utilities, and social networking. In the physical space, skills and human capital are considered as arguably the most important element. For instance, it is argued that the greatest competitive advantages of cities are qualities that attract the best and brightest from the world to a city (Bloomberg, 2011). This is supported by the fact that educated cities grow more quickly than less educated ones, since skilled cities are economically more productive and better at adapting to economic shocks (Glaeser & Saiz, 2003).

We summarize the different elements of the definitions of the Smart City concept below in Table 1. Further discussions on the conceptualizations and definitions of the Smart City are provided in (Hollands, 2008), (Caragliu et al., 2009) and (Nam & Pardo, 2011).

Table 1: Elements of "Smart City" Definitions

No	Description	Reference
Nature	Is a (1) forward-looking City in the areas of economy, people, governance, mobility, environment and lifestyle; (2) form of urban innovation; and (3) Intellectual Capital Profile of a City	(Giffinger et al., 2007), (Nam & Pardo, 2011), (Zygiaris, 2012)
Essence	Means (1) information access, bridging digital divide, lifelong learning, social inclusion and economic development; sustainable economic growth and urban development, higher quality of life; and wise management of natural resources; (2) innovative socio-technical and socio-economic growth of a city	(Hollands, 2008) , (Vasseur & Dunkels, 2010), (Zygiaris, 2012)
Approach	Involves (1) investments in human and social capital; (2) investment in traditional (transport) & modern (ICT) communication infrastructure; (3) promoting participatory governance and engagement of citizens; (4) technological, organizational and policy innovation	(Caragliu et al., 2009), (Nam & Pardo, 2011)

3 Methodology

3.1. Research Objectives & Questions

This study aims to capture the emerging understanding of the "Smart City" concept, examining the nature of smart city research and concluding on the overall research maturity and indications on areas where future research efforts could targeted. Specific objectives for the study include:

1. Strengthening the conceptual foundations of smart cities research by: a) developing an analytical definition for the "Smart City" concept by in-

tegrating existing definitions in literature; b) establishing conceptual similarities between "smart cities" and related concepts like Intelligent Cities, Ubiquitous City, Digital Cities, e-Cities, etc. and c) determining the major dimensions of the Smart City concept.

2. Determining the trend in "Smart Cities" research by identifying the major research themes and types in available smart cities publications and noting how these themes change over time.
3. Eliciting the research gaps by identifying research issues and questions from publications providing critical perspective, critique and lessons from planning, pilot development, and full-scale deployment of smart cities related initiatives.

Guided by these objectives, the study answers the following questions:

R1. How can the Smart City concept be defined and what are the major dimensions of the concept?

R2. Is there a discernible conceptual distinction among the three related concepts - Smart City, Intelligent City and Digital City? To what extent can previous studies in Digital and Intelligent cities fundamentally contribute to Smart City research?

R3. What trend can be observed in terms of theme, nature, and approach of research carried out in the Smart City domain?

R4. What are the areas of "Smart City" research that are relatively uncovered and to what extent are the governance aspects of smart cities studied?

3.2 Research Method

The research method adopted in the study combines research mapping and visualization technique with content analysis of scholarly publications used in Scientometric or Bibliometrics studies. The main source of data was journal articles and conference papers related to smart cities or intelligent cities provided in the Scopus Database - the largest abstract and citation database of peer-reviewed literature and quality web sources. Our decision to include publications on intelligent cities as part of the publications on studies of smart cities is based on the results of preliminary analysis of the definitions of the three related concepts (digital, intelligent and smart city) presented in Section 2. *Our analysis showed that the con-*

cept of intelligent city is significantly closer to smart city when compared with the digital city concept.

By taking publication as the unit of analysis, each publication is mapped to a number of dimensions – defining of key terms for the publication, the research theme addressed in the publication, the nature of research documented in the publication, the overall approach adopted in the research, and aspects of the Smart city concept addressed in the research. Microsoft Excel was used as analysis tool while "VosViewer" and "Pajek" - Program for Large Network Analysis were used for mapping and visualizing of the research landscape. The details of our mapping and analysis are discussed in the sub-sections below.

Selecting Publications

The source of data for our research is the Elsevier's Scopus Abstract and Citation database. We considered all publications in the database with the terms – "Smart City" or "Intelligent City" in their titles, abstracts or keyword lists. The same query was run a number of times between the period October 2011 and March 2012, to track new articles. Given that over 70% of the available publications were published within the past five years, all available 209 publications were considered initially in analysis. After reviewing each publication for relevance and removing publications without abstracts, we were left with 170 publications. The 170 publications were exported from the Scopus to Microsoft Excel for further analysis.

Generating the Publication Map

The mapping process entailed determining the nature of research contained in the publication, research approach adopted, aspects of the Smart City concept addressed in the research, and the neo-classical dimensions of the smart city concept related to the publication. For all four dimensions, our strategy was to start off with an initial set of possible values or labels and extend the categories as they emerge from the publications. The initial set of values defined for the four dimensions are highlighted below:

1) *Nature of Research* – describes the nature of research in the publication. A scheme combing the traditional classification of research in social science with the design-oriented research in computing and engineering was adopted. Publications were classified as (Heeks & Bailur, 2007)(Grönlund, 2004): polemic, debate, position, conceptualization, theoretical, theory development, theory testing, survey, design, or simply descriptive.

2) *Research Approach* – the methodological aspect of reported research comprises (Grönlund, 2004): single and multiple case study approach, comparative analysis, empirical analysis, action research, modeling and

simulation, experimentation were considered as options. When no specific approach is reported or implied in the abstract, the research approach was simply considered to be analytical.

3) *Research Themes and Sub-themes* – the initial set of themes were related to the classical policy cycle for any major initiative, in addition specific themes related to improving current understanding of smart cities, policy and strategy, models and frameworks, technology, governance, organizational processes in smart city initiatives or projects.

4) *Smart City Dimension* - the initial set of dimensions specified for the smart city concept include People, Economy, Mobility, Natural Environment, ICT Infrastructure, Lifestyle and Public Administration (or public governance).

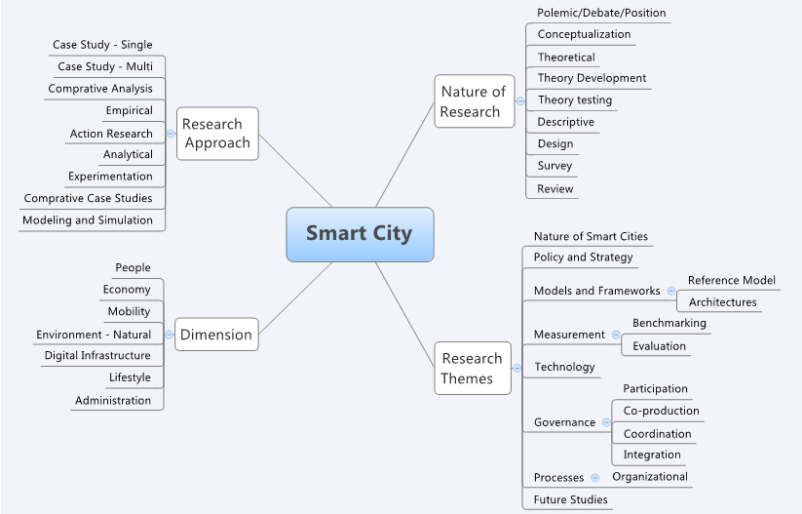

Figure 1: Taxonomy for Analysis Dimensions

Analyzing the Publication Map

After mapping each publication along the four dimensions described above, pivot tables were generated to summarize the publications along each of these dimensions to produce corresponding tables and graphs showing frequency counts and trends over years. The second type of analysis involved organizing and visualizing the research domain based on the titles, keywords, generated research themes and sub-themes as well as abstracts of the publications. The typical work-flow for domain visualization

was adopted using the VosViewer and Pajek tools. See Figure 1 and Table 2 for the taxonomy and parameters for the analysis respectively.

Table 2: Parameters for Analysis

Unit of Analysis	Individual publication
Measure	Counts of Attributes – Keywords, Title, Themes and sub-themes
Similarity measure	Co-term based using VosViewer Mapping and Clustering algorithm
Visualization	Pajek "Draw" algorithm

4 Analysis

This section presents an analysis of the research publications based on the methodology described in Section 3 as the basis for answering the research questions. Section 4.1 examines the elements and dimensions of the smart city concept, section 4.2 attempts to determine the similarities and differences between the Smart, Intelligent and Digital city concept. Section 4.3 explores the observed trends in Smart City research, followed by analysis of research gaps in the domain in Section 4.4.

4.1. Elements and Dimensions of the Smart City Concept

This section analyzes the smart city definitions provided in Section 2.3 to obtain the nature of smart cities, the kind of goals they are built to support, and their elements.

From the definitions, we identify three basic attributes of the Smart City concept as an "actual city" a form of urban innovation". First, Smart cities are characterized by the "high intellectual or human capital" needed to support continuous innovation and address problem or challenges. Second, in terms of goals, smart cities aim at social inclusion, significantly improved quality of life and economic development. Third, Smart city policies also target development of human capital through lifelong learning, optimal management of natural resources, and sustainable urban development in general.

Aspects of the smart city concept include: participatory governance, human capital development, ICT infrastructure development, technological innovation, organizational innovation, policy innovation, integration of

city endowments, and developing active self-decisive citizenry. Details are provided in Table 3 below.

Table 3: Analysis of "Smart Cities" Definitions in Literature

No	Description	Summary
Nature	○ Is a forward-looking City in economy, people, governance, mobility, environment, and living ○ Is urban innovation ○ Is intellectual capital of a city	○ Forward looking city ○ Urban Innovation ○ Intellectual capital
Purpose	○ Means to Information access ○ Means to lifelong learning; ○ Means to bridging the digital divide; ○ Means to social inclusion ○ Means to economic development ○ Means to high quality of life ○ Means to wise management of natural resources, ○ Means to dramatically improve their citizens' quality of life ○ Means to encourage business to invest ○ Means to creating a sustainable urban environment ○ Means to sustainable economic growth ○ Means to address innovative socio-technical and socio-economic aspects of growth	○ Information access ○ Lifelong learning ○ Bridging digital divide ○ Social inclusion (2) ○ Quality of life (2) ○ Economic development (4) ○ Natural resources management ○ Sustainable urban development
Elements	○ Includes participatory governance ○ Involves investments in human and social capital ○ Involves investment in traditional (transport) and modern (ICT) communication infrastructure ○ Includes technological, organizational and policy innovation ○ Involves smart combination of endowments ○ Involves activities of self-decisive independent and aware citizens	○ Participatory governance ○ Investment in human capital ○ Investment in social capital ○ Investment in communication infrastructure ○ Technological innovation ○ Organizational innovation ○ Policy innovation ○ Integration of endowments ○ Activities of self-decisive citizens

4.2 Conceptual Analysis of Smart Cities and Related Concepts

In this section, we attempt to identify the similarities and differences between the smart city concept and intelligent and digital cities.

Digital cities by their nature are considered to be some form of an extension – a virtual extension of a real city. In a weak sense, it is synonymous to a label assigned to cities with good ICT infrastructure or that widely employ ICT applications. Similar to Smart cities, digital cities are targeted at democratic participation, economic development and social cohesion. Despite the wide applicability of Digital city concepts, its elements are limited to mainly ICT infrastructure or digital networks and software applications.

Intelligent City as a concept appears to lie between the smart city and digital city concept. Intelligent city is conceived as a real city endowed with collaborative, learning, and innovation environments or spaces. The Intelligent city concept is also considered as a transformational instrument in urban development. Core purposes for intelligent city initiatives center on transformation of lifestyle, work and recreational activities in addition to sustainability of associated cities. Similar to the smart city concept, an important objective of intelligent cities is developing the problem solving capabilities of the cities.

Aspects of intelligent city include the ICT infrastructure development, development of intelligence infrastructure and services, in addition to building institutional leadership and organizational capacity of cities. We summarize the similarities and difference among these concepts in the Tables 4 and 5 below.

Table 4: Similarity of Smart City concept to Intelligent- and Digital City concepts

Similarities	Intelligent City	Digital City
Nature	Like smart city, intelligent city concept: o Serves as metaphor for real cities o Emphasizes on urban innovation o Are transformational	Like smart city, digital cities are characterised by: o High urban ICT adoption and usage
Purpose	Like in the smart city concept, intelligent cities also: o Focus on urban sustainability o Focus on impact on different aspect of urban life	Like smart cities, digital cities supports: o Includes socio-economic development and other aspects of urban life
Elements	Like smart cities, intelligent cities also: o Involve ICT infrastructure development o Involve creativity and social capital development	Like smart cities, digital cities also: o Involve ICT infrastructure development

Based on the analysis here, we note that the three terms - smart-, intelligent- and digital city are closely related concepts particularly in terms of their purpose. When considering the constituent elements of the concepts,

digital city is restricted to ICT infrastructure and services. The intelligent city concept in addition to the basic ICT infrastructure and services includes other specialized technical elements such as "intelligence" infrastructure to support acquisition of information (instrumentation) and learning. The intelligent city also includes elements that involve the development of innovation.

Smart city elements include those of the intelligent city in addition to socio-organizational and institutional infrastructure to support specific policy domains and governance mechanisms for integrating the solutions to concerns in the different domain.

Table 5: Difference between Smart City Concept and Digital- and Intelligent City concepts

Difference	Intelligent City	Digital City
Nature	Smart city concept places relatively emphasis on human aspect of urbanism, while intelligent focuses more on the technical supporting infrastructure and services.	Digital cities appear to be virtual extensions of real cities, whereas smart cities are conceptualized as "real cities".
Purpose	The scope of intelligent cities initiatives are relatively narrower than those of smart cities	The scope of digital cities initiatives are even more limited or focused when compared with smart cities.
Elements	Smart cities emphasizes integration among elements, while elements of intelligent cities are more specialized and standalone	Digital cities are characterized largely by ICT infrastructure and services, whereas smart cities involve activities in all major aspect of city development

4.3 Trends in Smart City Research

This section presents the trends in smart city research based on the analyzed publications. The information on research themes is presented in Section 4.3.1 followed by analysis of trends in the nature of smart city research in Section 4.3.2. The research approach adopted in smart city research is presented in Section 4.3.3. The section is concluded with discussion on research gaps in section 4.3.4.

4.3.1 Research Themes

This section on smart city research themes provides information on the broad research areas and specific themes, and recurring smart city research topics extracted from titles, keywords, abstracts, themes, of publications.

Research areas and themes of publications were mapped into five broad research areas: 1) Smart City attributes; 2) Smart City implementation; 3) Smart City Policy domains; 4) Management and Governance of Smart Cities and 5) Foundations of Smart cities. The first research area on city attributes involves investigation of one or more attributes of a smart city such as its population, size, employment rate, etc. and relationship among these attributes. The second research area on Smart City implementation include works aiming to provide models, tools, and guidelines for developing smart cities. This category of work covers discussions on experiences and success factors for smart cities. The third research area on Smart city policy domains includes research on different policy domains such as transportation, urban infrastructure management, energy, and health. Management and governance constituting the fourth research area includes works addressing how smart cities initiatives could be planned, managed and governed. This category also covers the regulations and standards issues in smart cities. The fifth category of research on foundation of smart cities aims at providing better domain understanding. For example, work in this category includes conceptualizations of smart cities and studies to understand the evolution and future of smart cities. See Table 6.

Table 6: Thematic Categories for Smart Cities Research

City Attribute	○ Population Growth
Implementation	○ Models and Frameworks ○ Success Factors ○ Information Sharing
Policy Domains	○ Intelligent Building ○ Urban Infrastructure Management ○ Sustainable Mobility ○ Intelligent Transportation ○ Energy and Technology ○ Human Capital and Employment ○ Education and municipal governance ○ ICT Infrastructure, Applications and Services
Management and Governance	○ Governance ○ Integrated urban planning ○ Measurement ○ Organization ○ Policy and Strategy ○ Standards and Regulations
Foundations	○ Future Studies ○ Nature of Smart Cities ○ Trends in e-Cities

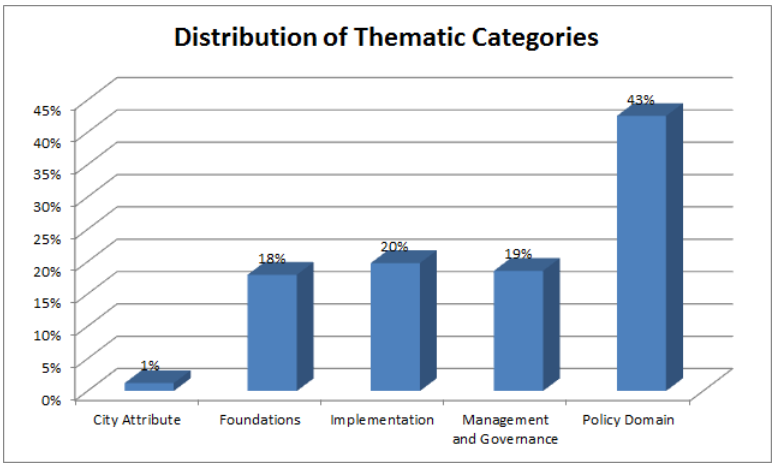

Figure 2: Distribution of Major Smart City Research Areas

Analysis of the thematic category mappings in Figure 2 shows that about 43% of the available publications focus on different policy domains. Research on implementation aspects of smart cities accounts for about 20% of the publications while research on management and governance accounts for about 19% of the publications. Studies on the foundational aspects of smart cities include about 19% of publications whereas publication volume on specific smart city attributes is very low – about 1% at the moment.

Regarding concrete themes, the top four most common research themes are: 1) technology – about 29% of the publications; 2) nature of smart cities – roughly 17% of the publications; 3) model and frame-works - about 13% of the publications and; 4) policy and strategy – roughly 8% of the publications. Figure 3 below provides details of this distribution.

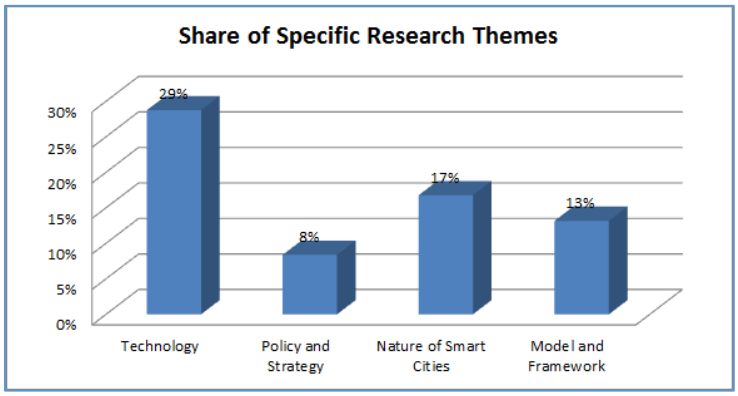

Figure 3: Share of Most Common Smart City Research Themes

In addition to information on research areas and themes, recurring topics appearing in the titles, keywords and abstracts are discussed next. Two kinds of analysis were carried out to produce this information from the input text. The first is the clustering of the key terms representing the text, and the second is the mapping of these key terms into a two dimensional surface, in such a way that similar concepts are located close to one another. The VosViewer tool was used for both visualization and mapping. The resulting maps could be visualized using several applications in addition to the VosViewer. The Pajek tool was used for visualizing the maps generated from VosViewer. Figures 4 and 5 are examples of maps generated using Pajek. Information provided on the generated maps is discussed below. *Note that "topics" as used below in the various text analytics tasks connotes semantically related (or co-occurring) terms over a number of smart city publications. Therefore, these topics highlight "inherent structures" in the body of smart city literature.*

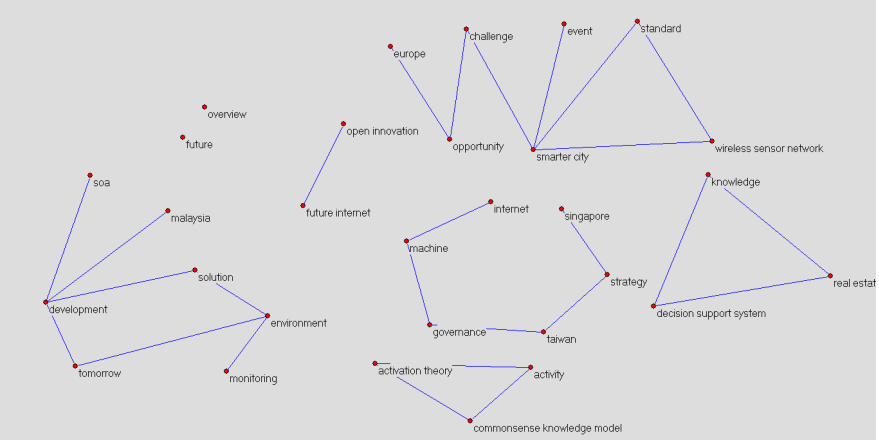

Figure 4 Most Representative Terms generated from Titles of Publications

Topics generated from Publication Titles – the first set of analysis involved titles of publications. The map resulting from this analysis is provided in Figure 3. Some of the representative topics generated from titles of publications include: 1) Wireless Sensor Network Standards in Smart Cities, 2) Event-driven design in smart cities, 3) Challenges in Smart City, 4) Decision support system as Knowledge management solution for Real Estate, 5) Smart city strategies, examples from Taiwan and Singapore, 6) Governance of machine-to-machine interaction; 7) Supporting activities

through common sense knowledge modeling and activation theory; 8) Solutions for environmental monitoring; 9) Developing Service-oriented architectures-based solutions; 10) Open innovation and future internet. *We may summarise these topics under 3 broad topics – Technical infrastructure and paradigms for smart cities, Strategy and management of smart cities and Smart city solutions.*

Topics generated from Keywords – similarly, keywords provided in publications were analyzed to generate recurring topics. The resulting map is presented in Figure 5. Examination of the map produces the following topics: 1) intelligent or smart transport management, 2) GIS and City infrastructure development monitoring; 3) Mobile agent-based implementation of m2m interactions in Internet of Things (IoT), 4) Living lab approach to m2m interaction in IoT, 5) Knowledge management and govern-ance of sustainability, 6) Urban infrastructure management in Smart or Ubiquitous cities, 7) Business models for mobile services, 8) Mobile Wireless Networks, 9) Commonsense knowledge modeling for spreading activation, 10) web services and simulation of intelligent vehicle control, and 11) E-Governance and sustainable development. *From these topics, four broad categories of topics can be identified - Smart City Solutions; Technical Infrastructure and Paradigm for Smart Cities; Management and Governance of Smart Cities and Business aspects of Smart Cities.*

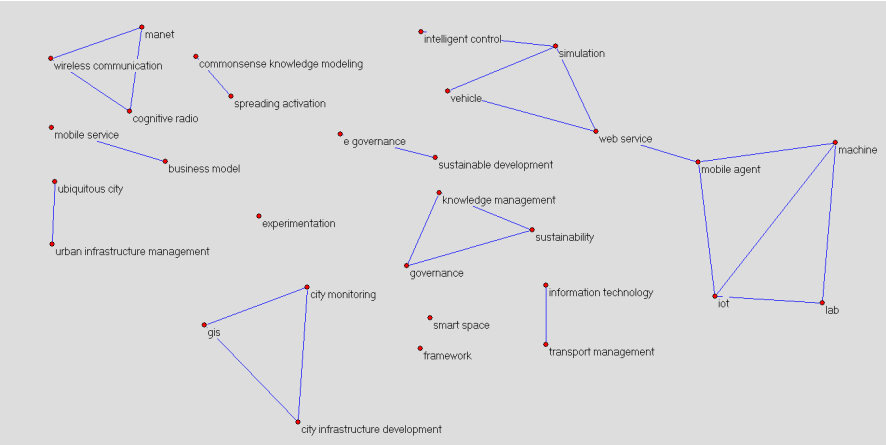

Figure 5 Most Representative Terms generated from Publication Keywords

These text-based analyses provide the complementary information on the underlying cognitive structure of the smart city domain based on the avail-

able publications. We consolidate the resulting high level topics from two analyses in Table 7 below.

Table 7: Parameters for Analysis

Source of information	High-level topics detected from text analysis
Title of publication	1) Technical infrastructure and paradigms for smart cities, 2) Strategy and management of smart cities and 3) Smart city solutions
Keywords	1) Smart City Solutions, 2) Technical Infrastructure and Paradigm for Smart Cities, 3) Management and Governance of Smart Cities and 4) Business aspects of Smart Cities

Coverage of Smart City Dimensions in Research Publications – An important perspective to understanding smart cities is through its dimensions (please see Figure 1). The majority of the publications focused on only one specific dimension – about 71%. Research involving one or more dimensions (e.g. education and governance) constitutes about 21% of the publications, whereas publications addressing all dimensions as a whole were about 7%. See Figures 6 and 7. In terms of relative coverage of specific dimensions, most of the publication in smart cities is on ICT Infrastructure (or technology). The next area of focus is on governance, followed by people.

With respect to governance, topics found in publication set include reform, integration, policy and strategy, measurement, standards and regulation, public engagement and partnership. Within Governance related publications, the most common governance topic is Policy and Strategy (29%), followed by Measurement (24%) and Standards & Regulations (18%). See Figure 8.

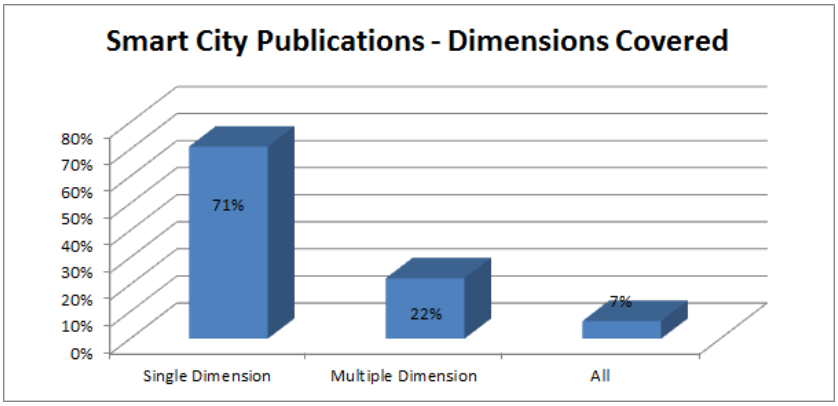

Figure 6: Distribution of Dimensions of Smart City Research

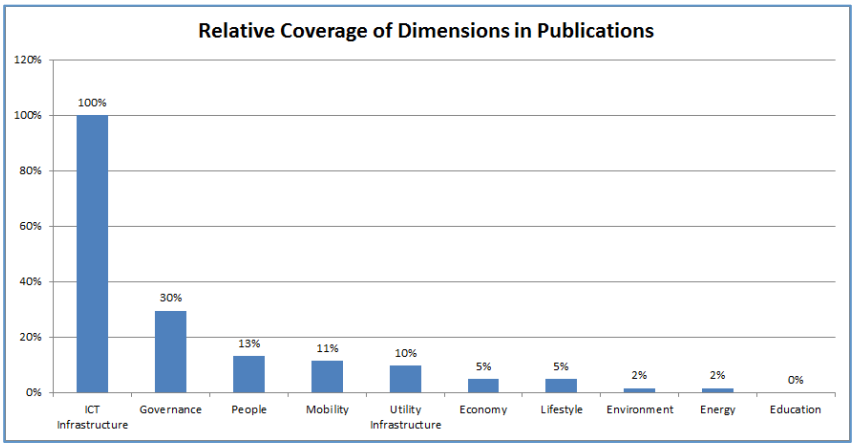

Figure 7: Distribution of Themes of Smart City Research

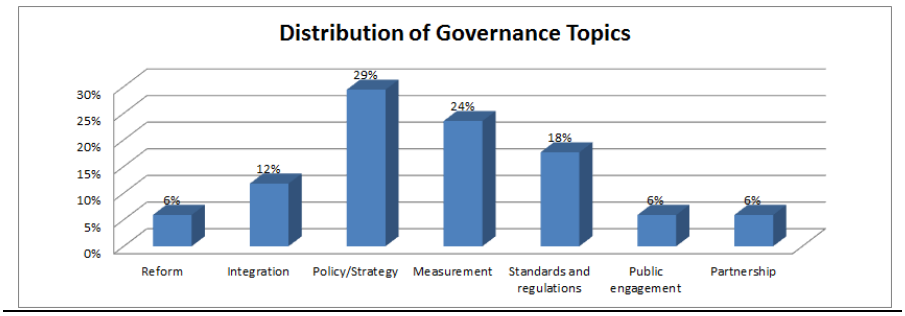

Figure 8: Distribution of Governance Topics

4.3.2 Nature of Research

This section reviews the nature of research characterizing smart city domain. About 41% of the publications contained research works that were simply descriptive with no specific orientation. Publications describing Design Research made up about 32% of the total publications. Research on conceptualizations of smart cities constitutes 9% of the whole publications. Research works on Theory development and testing about smart cities account for 5% and 1% of the publications respectively. The number of Survey, theoretical, polemic, position publications are very few (virtually non-existent). Figure 9 provides details of the distribution of smart city research based on their nature.

In terms of the trends, close to 60% of the total publications on smart cities were published in the 2011 alone and since 2010 there has been 200% increase in annual smart city publication volume. Considering specific research types, research on design and conceptualization have doubled from 2010 to 2011, while general descriptive research increased more than 6 folds from 2010 to 2011.

From these facts we gather that about 40% of research publications on smart cities are simply descriptive which no discernible research type or philosophy. About 50% of the remaining research works with discernible orientation are design oriented. This could be attributed to the fact that Computer science and engineering are currently by far the subject areas contributing most to smart cities research. After design re-search, works on smart city conceptualization are next indicating ongoing efforts to better understand the concept. The relatively few numbers of theory-related publications and the rapid growth could be attributed to relative young nature of the research domain.

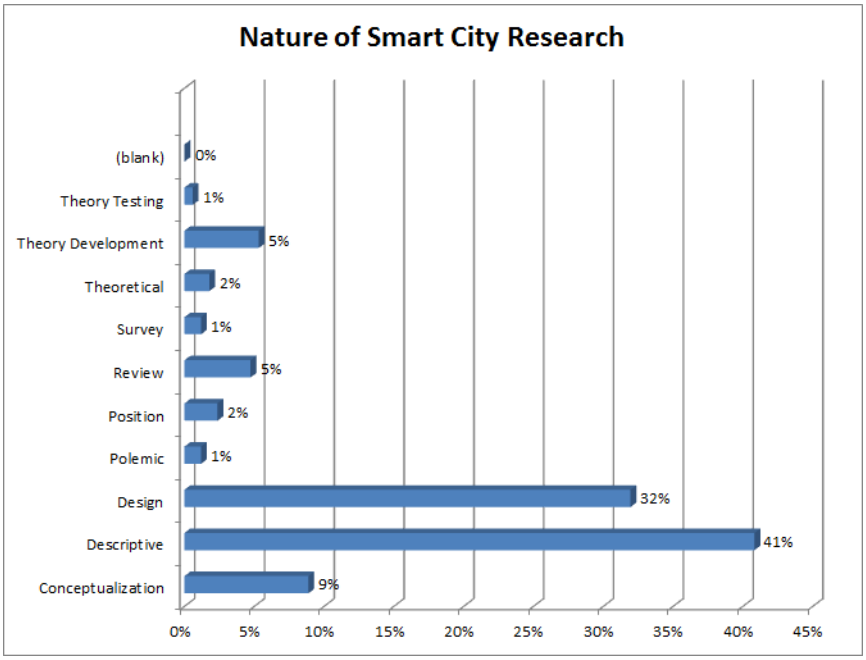

Figure 9: Distribution of Nature of Smart City Research

4.3.3 Research Approach

In this section we summarize the smart city research domain based on the research approach adopted, see Figure 10. Results show that about 46% of the research publications have no clear or discernible research approach but offer logical analysis of the problems and solutions (i.e. Analytical approach). Research work involving development of one form of technical artifact or another as solution to a problem (i.e. development approach) constitute about 23% of the publications. Research based on experimentation and case studies equally account for about 8% of the research publications. Approaches including - modeling and simulation, survey, grounded theory, living lab, and empirical research have also been employed in smart city research albeit to very limited level. In terms of trends, the use of case studies (multi-case studies in particular) grew significantly from 1 publication in 2010 to 9 in 2011, with respect to other methods such development. In addition, experimentation and comparative analysis in smart city research grew by 300% and 200% respectively.

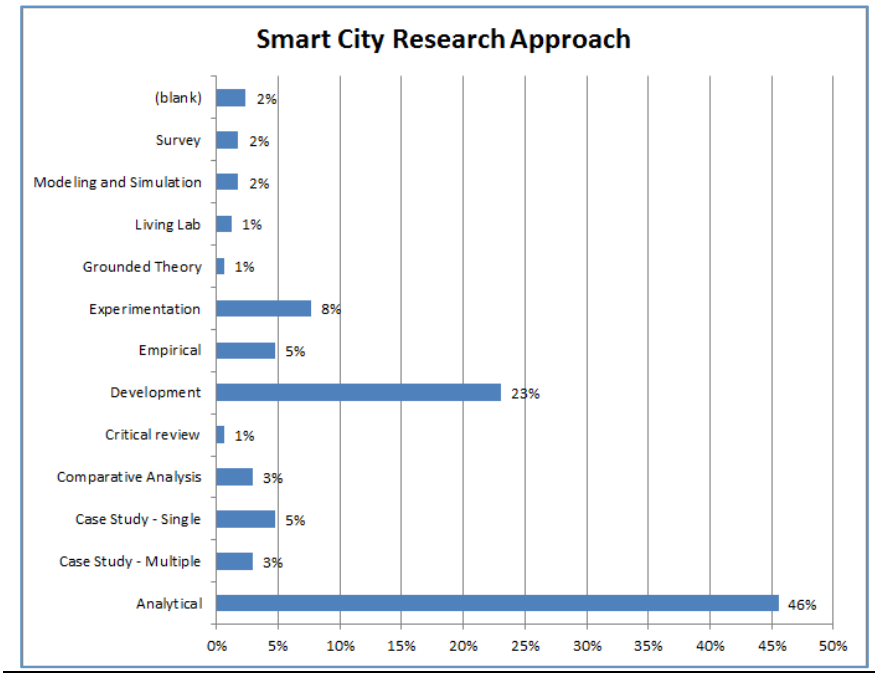

Figure 10: Distribution of Smart City Research Approach

4.4. Gaps in Smart City Research

This section summarizes the research gaps arising from the analysis of the research themes, type, and approach of the available smart city publications in Section 4.1 and the fundamental research issues obtained from smart city literature in Section 4.2.

4.4.1 Gaps Arising from Research Themes, Type, and Approach

We arrive at the research gaps by identifying research areas, themes, types, and approaches that are relatively under-represented in the set of smart city publications analyzed in this study. See Table 8. These various thematic and paradigmatic topics could be combined to generate concrete research scenarios that potentially contribute to the smart city research and practice domain. *Given the relative maturity of the domain, interdisciplinary studies on concrete smart city cases including success factors and challenges require attention to build theoretical foundations*. From the analyzed publications, another major observation on research gap is the relative disconnect between smart cities research and the traditional, more mature studies in urban informatics. *In summary critical research to better understand different aspects of existing smart cities are very few if at all available*.

Table 8: Smart Cities Research Aspects with relatively low numbers of publications

Research Areas	o Research on Smart City characteristics o Foundations of smart cities o Management and Governance o Lessons and Experiences on Smart City Implementation
Research Themes	o Urban Infrastructure Management o Smart City Success Factors o Information Sharing and Service Integration in smart cities o Measurement of Smart Cities o Human capital and employment o Sustainable Mobility and Intelligent transport o Standards and regulatory framework for smart cities o Policy and decision optimization across smart city domain
Dimensions	o Education o Energy o Lifestyle or Smart Living o Smart Economy o Utility Infrastructure o Mobility o People
Nature of Research	o Theory development and testing o Review Smart Cities research and practice o Survey of Smart Cities Initiatives o Position papers on aspects of Smart Cities
Research Approach	o Modeling and simulation o Living Lab

	o Empirical o Critical Review o Comparative analysis o Case studies

4.5 Examples of Research Challenges from Literature

This section presents examples of research challenges discussed in some of the selected research publications. These examples serve as concrete instances of problems in the smart city research areas listed in Section 4.4.1. Four categories of issues are described here - 1) Fuzziness or conceptual ambiguity of the term "smart city", often conflated with terms like intelligent and digital city; 2) Dialectics of Suburban Policy – arguments on the fallacy of suburban policy as a greener option to pro-concentration and city growth policy; 3) Top down versus bottom up transitional strategy for smart city development; and 4) Participatory urbanism – how can citizens serve as human sensors and source of data. *With respect to the gaps identified in Table 8, the first challenge is related to the "Foundations of smart cities" research area. The second and third challenges are related "Lessons and Experiences on Smart City Implementation" area. The fourth challenge is in the area of "management and governance" with focus on the people dimension.* These four categories of issues are discussed below:

1. Fuzziness and conceptual ambiguity of "Smart City" (Hollands, 2008) – There is general consensus on the fuzziness of smart city as a concept. For instance, existing literature have associated the smart city concept with IT and creativity and urban entrepreneurship. Research in this would address questions like - Are smart cities high-tech variations of urban entrepreneurialism? How to distill substantive issues from hype or marketing use of the "Smart City" terms? How to have a more critical look at urban labeling such as smart city?

2. Dialectics of Suburban Policy (Glaeser, 2011b) – This research line involves producing empirical evidence to support either the suburban or city center concentration or pro-urban option. There are arguments that giving the well-accepted facts that cities provide economic, health, and educational benefits that accrue from face-to-face social networking, policies to favoring citizens settling in suburbs should be carefully rethought. The thesis is linked to the "super-linear scaling" effect - that socio-economic properties of cities increase faster than a direct linear relation to their population.

3. Building Smart Cities Top down or by Retrofitting (Biello, 2011) – This line of research seeks to determine the better strategy for developing smart

cities. The top down school of thought argues that smartness must be engineered into attributes, such as sustainability, must be built into infrastructures. Reference models for building smart cities top down are beginning to emerge. Smart city planners could formulate a planning agenda based on the reference model. However, from the bottom-up perspective, planned smart and eco-cities are fizzling out mainly because of cost.

4. Participatory urbanism or Citizen Science (Paulos, Honicky, & Hooker, 2009) – This research line explores how new "personal instruments" such as mobile phones enable an entirely novel and empowering genre of mobile computing usage called citizen science. The problem centers on how individuals or citizens can become to active participants and stakeholders as they publicly collect, share, and remix measurements of their city that matter most to them.

5 Findings

This section summarizes the findings of the study with respect to the research questions:

R1 - Smart City and Its Dimensions - From the definitions, we identify three basic attributes describing the nature of smart cities as "actual cities" that are results of "urban innovation". Smart cities are characterized by the "high intellectual or human capital" needed to support continuous innovation and address problem or challenges. In terms of goals, smart cities aim at social inclusion, significantly improved quality of life and economic development. Smart city policies also target development of human capital through lifelong learning, optimal management of natural resources and sustainable urban development in general.

R2 - De-conflating Smart, Intelligent and Digital Cities – the three terms - smart, intelligent, and digital city are closely related concepts particularly in terms of their purpose. When considering the constituent elements of the concepts, digital city is restricted to ICT infrastructure and services while the intelligent city concept is an addition to basic ICT infrastructure and services including other specialized technical elements such as "intelligence" infrastructure to support acquisition of information (instrumentation) and learning. The intelligent city also includes elements that involve development of innovation. Smart city elements include those of the intelligent city in addition to socio-organizational and institutional infrastructure to support specific policy domains and governance mechanisms for integrating the solutions to concerns in the different domain. *However, the*

notion of intelligent city is significantly closer to that of Smart City when compared with digital city.

R3.1. - Smart City Research Themes – Five broad areas of research were obtained from the analysis of the smart city research publications - 1) Smart City attributes; 2) Smart City implementation; 3) Smart City Policy domains; 4) Management and Governance of Smart Cities and 5) Foundations of Smart cities.

Mappings to these research areas show that about 43% of the available publications focus on different policy domains. Research on implementation aspects of smart cities accounts for about 20% of the publications. Research on management and governance accounts for about 19% of the publications. Studies on foundational aspects of smart cities include about 19% of publications, whereas publication volume on specific smart city attributes is very low – about 1% at the moment.

Considering concrete research themes, the top four most common themes are: 1) technology – about 29% of all publications; 2) nature of smart cities – roughly 17% of the publications; 3) model and frameworks - about 13% of the publications and; 4) policy and strategy – roughly 8% of the publications.

In terms of relative coverage of specific smart city dimensions, by far most of the publications in Smart cities are on ICT Infrastructure (or technology). The next area of focus is on governance – about one-third of the publications on ICT infrastructure, followed by people.

R3.2. - Nature of Smart City Research - About 41% of the publications contained research works that were simply descriptive with no specific orientation. Publications describing Design Research made up about 32% of the total publications. Research on conceptualizations of smart cities constitutes 9% of the whole publications. Research works on Theory development and testing about smart cities account for 5% and 1% of the publications respectively. The numbers of survey, theoretical, polemic, position publications are very few (virtually non-existent). In terms of the trends, close to 60% of the total publications on smart cities were published in the 2011 alone and since 2010 there has been 200% increase in annual smart city publication volume. Considering specific research types, research on design and conceptualization have doubled from 2010 to 2011, while general descriptive research increased more than 6 folds from 2010 to 2011.

R3.3 - Approaches to Smart City Research - Results show that about 46% of the research publications have no clear or discernible research approach

but offer logical analysis of the problems and solutions (i.e. Analytical approach). Research works involving development of one form of technical artifact or another as solution to a problem (i.e. development approach) constitute about 23% of the publications. Research based on experimentation and case studies equally account for about 8% of the research publications. Approaches including - modeling and simulation, survey, grounded theory, living lab, and empirical research have also been employed in smart city research albeit to very limited level.

In terms of trends, the use of case studies (multi-case studies in particular) grew significantly from 1 publication in 2010 to 9 in 2011, with respect to other methods such Development. In addition, experimentation and comparative analysis in smart city research grew by 300% and 200% respectively.

R4.1 - Gaps in Smart City Research - Given the level of maturity of the domain, interdisciplinary studies based on concrete smart city cases providing more insight to success factors, challenges and peculiar issues are to enable the development of sound theoretical foundation for the domain. A clear gap resulting from subject area contribution pattern in smart city research is the relative disconnect between smart cities research and the traditional, more mature studies in urban informatics.

R4.2 - Governance of Smart City – After ICT Infrastructure policy, publications on governance are next in terms of volume of production. Specifically about 17% of the publications focusing on specific smart city domains address governance. Governance topics found in reviewed literature include reform, integration, policy and strategy, measurement, standards and regulation, public engagement and partnership. Within Governance related publications, the most common governance topic is Policy and Strategy (29%), followed by Measurement (24%) and Standards & Regulations (18%).

6 Conclusions

The objective of this study was to determine the state of smart cities research and in particular the extent to which governance issues are addressed in the domain. The results show that the research domain is just developing given that over 75% of the publications in the domain were produced between 2009 to date and there have been over 200% increase in publication volume since 2009. A significant proportion of the works have no specific research orientation, paradigm or methodology currently char-

acterizes the smart city research landscape. These facts are symptomatic of relatively new domains. One of the most striking features of smart city research is the clear dominance of computing and engineering as the contributing subject areas. Consequently, most of the research with a discernible approach were generally design oriented, focusing on developing technical artifacts. Perhaps more surprising is the gap between current smart cities research and root disciplines such as urban planning and more recently urban informatics. *We conclude from this study that critical research efforts to better understand different aspects of existing smart cities are very few if at all available.*

Therefore, in addition to the expected growth in smart cities research, emphasis will likely shift to studies on concrete cases as basis for foundational insight into the nature of smart cities and at the same time leveraging existing knowledge in urban planning and city transformation for theoretical grounding.

An important limitation of the mapping exercise carried out in the study is that the mapping was restricted to the analysis of titles, abstracts, and keywords of the publications. Full text where only considered or read when the abstract where unclear enough to determine the necessary information about the publications.

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