A META-ANALYSIS OF SMART CITY RESEARCH AND ITS FUTURE RESEARCH IMPLICATIONS

SMART CITY – CURRENT STATE & FURTHER IMPLICATIONS

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ABSTRACT

The aspired potentials of the "Smart City" (SC) and its deficits in practice are essential reasons why the subject is assigned to a rapidly growing body of literature. This situation requires a specific review of the literature summarizing the research efforts to date into research branches and topics, unifying essential basic concepts and thus forming a solid basis for further research. The present study first derives a basic structure of research by an analysis of the available literature reviews. Subsequently, a systematic examination of SC literature by means of an EBSCO data query identifies the current research topics and compiles a comprehensive view of the research topics. The present study is therefore not only of interest for scientific use, but also offers practitioners an overview of the various sub-areas of a SC, as well as of the currently available findings and experiences in relation to the implementation of SC (sub-)projects.

Keywords *– Digital City, Literature Review, Meta-Study, Smart City, Sustainable City*

INTRODUCTION

Cities are expected to be at the center of the anticipated growth in world population in the next century such that two thirds of the world's residents will live in conurbations by 2050 (United Nations 2015). It is conceivable that such a large increase in the urban population will pose major challenges to public administration both at the local urban level and beyond at the cross-regional level. In particular, this rapid urbanization will lead to depopulation of rural areas, overload of the existing urban infrastructure, overuse of obtainable urban resources and ultimately to a decline in the urban quality of life due to the selective densification of the population. Therefore, public authorities responsible for addressing these defiances need to find 'smart solutions' for forward-looking public management (Cocchia 2014). To encounter this necessity of 'smartness' in urban planning and development, practitioners and scientists try to resolve the problems of enlarged mega-cities by adopting a 'smart city' (SC) approach, i.e. a public urban management

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system that uses information and communication technology to perceive, monitor and manage the course of daily life within the city in an 'intelligent' manner (Townsend 2013; Deakin and Al Waer 2011).

In order to meet this demand for solutions and planning approaches in public municipal administration, scientific literature concerning SC concepts increased considerably in recent years and even eclipse the contributions for the concept of a 'sustainable city' which used to be the leading academic concept for public urban planning and development until 2013 (Jong et al. 2015; Fu, Zhang 2017; Trindade et al. 2017). However, the research landscape is complex and connections among the individual papers are often not discernible due to the different forms of a SC's basic idea (Fu and Zhang 2017; Meijer and Bolívar 2016). This fragmentation and splintering of the research field forces scientists to look beyond their own research discipline in order to construct a comprehensive approach that includes "at its base, technology, management, and policy instruments" (Gil-Garcia et al. 2015, p. 79). Nonetheless, the current state of research with regard to literature reviews and meta articles has a very topic-specific focus (cf. Ruhlandt 2018; Petit-Boix et al. 2017; Trindade et al. 2017) and only few articles offer a holistic perspective that take the various contributions from different research disciplines into account (see for example Fu and Zhang 2017; Hayat 2016).

In view of the fragmentation of SC research and the lack of an overview of scientific progress in its various subfields, the field emerges as a patchwork of divergent approaches and definitions of a city's smartness. In this context, Fu and Zhang (2017) speak of a dense network of different urban development concepts with differentiated foci (cf. Fu and Zhang 2017, p. 113) concluding a scientific divide between the "sustainable city"-literature and the "smart city"-literature. In contrast, Cocchia (2014) as well as Öberg et al. 2017 argue that previous urban development concepts and definitions may be subsumed under the umbrella term of a 'smart city' as all these conceptualizations state different ways of "a key strategy to improve the quality of life […] of people living in cities all over the world" (Cocchia 2014, p. 41). In order to unify these different notions of a 'smart' city, scholars call for further research "aiming at increasing the collective understanding in this knowledge domain" (Mora et al. 2019, p. 83) and suggest "to study topics of importance for different groups and how they may be integrated into an improved understanding of the nature of smart cities" (Marrone and Hammerle 2018, p. 210).

Against this background, the purpose of this article is to summarize the progress that has been achieved so far by conceptual and empirical research in order to provide a comprehensive picture of the state of the art regarding the institutional anchoring and design of SC projects for the scientific and practical evolution of SC concepts, as well as for planning and controlling ongoing SC projects. Therefore, this article intends to broaden the knowledge about the state and direction of SC research in conjunction with the classification of SC literature in the scientific landscape and the designation of adjacent disciplines. In order to identify the relevant literature, the ensuing section describes the methodology of our systematic two-step literature review determining the various notions of a SC and assessing the scientific progress within the related subfields. Based upon the identified literature, section three reflects the development of the whole field of SC research since the 1980s and provides first insights into the evolution of the term 'smart city' and

the divergence in terminology. In doing so, section three relies upon the insights of previous literature reviews and juxtaposes the findings of these studies. In order to get a complete overview of the current state of the art in each of the subfields, we continue our literature analysis by quantitatively examining the content and scope of SC studies in section four. The article concludes by summarizing and discussing the results of the analysis and, finally, by providing implications and recommendations for further research concerning SC concepts in section five.

METHODS AND BASIC LITERATURE

In order to achieve a comprehensive overview of the current state of SC research incorporating all the facets of the urban development concepts, this meta-analysis refers to publications in scientific journals, as these sources reflect high-quality and up-to-date research (Webster and Watson 2002). The central point of a meta-analysis is the classification of the studies examined according to research orientation, content and method. To assess the research landscape and identify the prevalent major fields of SC research, we started our systematic literature review by searching for literature reviews in the EBSCOhost system using the Academic Search Complete, Business Source Complete and EconLit databases[1]. This query in title, abstract and keywords based on the terms 'literature', 'review', 'overview', 'state of', 'origin' and 'meta', resulted in 15 relevant studies. Section three examines these SC literature reviews in detail in order to gain insight into the evolution of the field and into the terminological divergence.

As a second step, we collected all scientific contributions to SC research by conducting another title and abstract query on the EBSCO databases for English, peer-reviewed scientific journal articles using various search terms that the previous SC literature reviews subsumed under the umbrella term of a SC[2] (cf. Fu and Zhang 2017; Cocchia 2014). After identifying a preliminary relevant set of articles, we cleaned up the record and deleted duplicates, prefaces, editorials and introductions, book reviews as well as ambiguous document types from set resulting in a basic population of 1,019 articles. In accordance with our conclusions from the previous sections, the database holds a very broad range of approaches stemming from different scientific disciplines (e.g. computer science, electrical engineering, ecology, administrative sciences or economics).

Due to our focus on the public administration of cities, we performed a preliminary classification of studies and separated the articles into five major clusters associated with the main direction of SC research: (1) empirical studies, (2) conceptual studies, (3) technological basic research, (4) other research and (5) non-relevant articles. Table 1 shows the results of the preliminary clustering for all major categories.

In order to assign the respective articles to the corresponding categories, the abstracts of the 1,019 studies were searched for their corresponding assignment. As can be seen in Table 1, 10% of the available studies, i.e. 103, could be assigned to empirical SC research, and every fifth study (212) to the field of conceptual SC studies. These 315 studies form the main sample of articles analyzed later on in section four. The articles assigned to the class of technological basic research and other research, i.e. 313 articles, contain further

findings on the technology used, the functioning and linkage of the various SC subsystems as well as on the ethical and legal evaluation of SC concepts. Thus, this body of literature states supplementary knowledge for the implementation of a SC and was set aside in the subsequent analysis. More than a third of the initial set (377 articles) contained studies dealing with algorithmic programming and the establishment of digital platforms serving as the basis for various SC applications. Although these studies provide a valuable contribution to the implementation of smart services from a microscopic point of view, they are too detailed to answer our research questions and were therefore sorted out as being irrelevant.

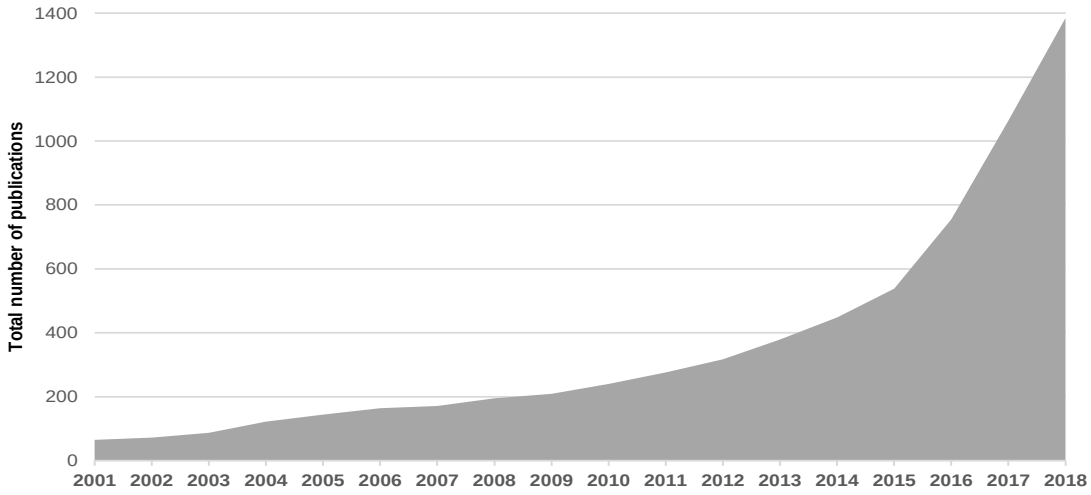
Table 1: Basic Classification of SC Research

Main Research Focus	Description	# of Articles assigned	Percentage
Empirical Research	Literature concerning the empirical deduction and verification by observation, surveys, experiments, secondary data analysis or content analysis	103	10%
Conceptional Research	Literature concerning conceptualization, operationalization, indicator and causal analyses as well as model development aiding to set the basic frame for empirical 'smart city' research	216	21%
Technological Basic Research	Literature concerning the technological architecture and infrastructure of 'smart cities' and providing additional knowledge to understand the technical foundation of smart services in the city	194	19%
Other Research	Literature which could not be classified in any of the aforementioned categories and might be viewed as auxiliary knowledge for a bigger picture of the issue.	129	13%
Non-relevant Research	Literature that either has a too fine-grained focus on a specific sub dimension of 'smart city' or shows very little or no clear reference to comprehensive smart city concepts.	377	37%
Total		**1,019**	**100%**

SMART CITIES: ORIGINS AND EVOLUTION OF THE FIELD

The term 'smart city' is essentially based on the discussion of long-term development cycles by Barras (1987). According to the author's findings, increasing urbanization is to be expected around the turn of the millennium because of technological progress in information and communication technology. This realization led to first considerations of the 'sustainable city' and the 'livable city' in the 1990s (Fu and Zhang 2017). Due to the spread and improvement of the Internet, as well as the constant progress of networking and processor performance in the early 2000s, networking and the broad application of information and communication technology in the urban setting became the focus of SC research.

Figure 1: Evolution of Smart City Research, 2001-2018



The market launch of smartphones, e.g. Apple's iPhone 2G in 2007 or Samsung's S4 in 2013, which united the functions of different, formerly separated devices into one and made the Internet and its applications transportable and mobile, laid the foundation for the new research field of the Internet of Things. Research in this area breathed new life into the idea of a 'smart city', i.e. the idea of a city offering a nexus of various interlinked services to its citizens. Thus, SC literature quadrupled its number of publications from 2013 to 2018 (cf. Hamman et al. 2017). Figure 1 shows this exponential development of the total number of publications. The diverse development of SC research, associated with the improvement in ICT adaptation to SC requirements and implementation difficulties, led to a scattered field of research with low cohesion among the various research topics. In addition to the persistent lack of comprehensive studies, the situation aggravtes standardization and unification of the various concepts, leading to a continuous development of isolated solutions for minor problems.

In addition to the underlying core topic, Table 2 shows the scientific orientation and the number of literature used. Thus, the work of Fu and Zhang (2017) reviewing 2,100 articles represents the most extensive work to date. Likewise, the literature reviews of Hamman et al. (2017) and Cocchia (2014) also provide a broad literature overview and a well-founded analysis encompassing over 700 articles. By and large, the investigation of the article samples of the literature reviews shows that only few reviews consider a broad range of literature and provides a comprehensive view with regard to the state of SC research. The larger part of the survey articles constitutes niche research covering less than 100 articles.

Table 2: Overview of Literature Reviews related to 'Smart City' Research

Author(s)	Year	Title	Core Topic	Articles Types Analyzed	Articles Sample
Carvalho J, Costa R, Marnoto S and Sousa C	2018	Toward a Resource-Based View of City Quality: A New Framework	Adoption (City Quality)	Conceptual & Empirical	186
Pereira G, Parycek P, Falco E and Kleinhans R	2018	Smart Governance in the Context of Smart cities: A Literature Review	Concepts & Components (Smart Urban Governance)	Conceptual	77
Ruhlandt R	2018	The governance of smart cities: A systematic literature review	Research Design / Models	Conceptual & Empirical	62
Fu Y and Zhang X	2017	Trajectory of urban sustainability concepts: A 35-year bibliometric analysis	General Overview	Conceptual & Empirical	2,145
Kummitha R and Crutzen N	2017	How do we understand smart cities? An evolutionary perspective	General Overview	Conceptual	161
Öberg C, Graham, G and Henelly P	2017	Smart Cities: A literature review and business model network approach discussion on the management of organisations	Business & International Relations	Conceptual & Empirical	45
Petit-Boix A, Llorach-Massana P, Sanjuan-Delmás D et al.	2017	Application of life cycle thinking towards sustainable cities: A review	Adoption (Urban Sustainability)	Empirical	24
Trindade E, Hinnig M, da Costa E et al.	2017	Sustainable development of smart cities a systematic review of the literature	General Overview	Conceptual	25

(continued)

Table 2: continued

Author(s)	Year	Title	Core Topic	Articles Types Analyzed	Articles Sample
Bolívar M and Meijer A	2016	Smart Governance: Using a Literature Review and Empirical Analysis to Build a Research Model	Concepts & Components (Smart Urban Governance)	Conceptual	15
Chauhan S, Agrarwal N and Kar A	2016	Addressing big data challenges in smart cities: a systematic literature review	Adoption (Big Data)	Conceptual & Empirical	38
Hamman P, Anquetin V and Monicolli C	2016	Contemporary Meanings of the 'Sustainable City': A Comparative Review of the French- and English-Language Literature	Concepts & Components (Urban Sustainability)	Conceptual	707
Meijer A and Bolívar M	2016	Governing the smart city: a review of the literature on smart urban governance	General Overview	Conceptual & Empirical	51
Gil-Garcia J, Pardo T and Nam T	2015	What makes a city smart? Identifying core components and proposing an integrative and comprehensive conceptualization	Concepts & Components	Conceptual & Empirical	NA
Cocchia A	2014	Smart and Digital City: A Systematic Literature	General Overview	Conceptual & Empirical	705
Tranos E and Gertner D	2012	Smart Networked Cities	Business & International Relations	Conceptual & Empricial	90

Beside the amount of literature considered, the scientific orientation of a literature overview is also decisive. It is interesting to note that almost all listed articles consider conceptual studies in their analysis, but a pure consideration of the empirical branch of SC research can only be found in Petit-Boix et al. (2017). This indicates a strong impact of the conceptual branch of SC literature and a gap between theoretical concepts and empirical findings.

In order to get detailed insights on the issues current research is dealing with, the meta-articles under consideration are grouped into five generic thematic areas: (1) adoption, (2) concepts and components, (3) research design / models, (4) business and international relations, and (5) general overview.

The adoption-related meta-analyses provide a systematic overview of implementation-related sub-themes such as success drivers, adversities, proliferation and usage. Chauhan et al. (2016) give a comprehensive outline of challenging situations and appropriate responses in case of the implementation of Big Data utilization in the SC. In contrast, Carvalho et al. (2018) move away from the technical discussion and take up a rather human-centered position.

The articles assigned to the cluster of concepts and components deal with the technical, managerial and organizational configuration of SC approaches such as definition, component analysis and description of core elements (cf. Gil-Garcia et al. 2015; Hamman et al. 2017; Petit-Boix et al. 2017; Pereira et al. 2018). The studies of Bolívar and Meijer (2016) and Ruhlandt (2018) summarize the body of literature with regard to the governance of SC systems aiming to develop a systematic scheme to structure previous research work and to develop proposals and guidelines on objectives, directions and procedures for future research projects. Tranos and Gertner (2012) study the positioning of cities in their business and political networks. By conducting a qualitative review regarding a SC's economic and political interdependencies, the authors deduce that there is a "need for smart cities to incorporate into their strategies a global inter-urban perspective" (Tranos and Gertner 2012, p. 182). Besides looking at the external economic relations of cities, Öberg et al. (2017) state that previous literature lacked in addressing business networks in cities but "rather focused on organisations (and individuals) as developing ideas resulting from societal initiatives" (Öberg et al. 2017, p. 480).

In addition to these thematically specific meta-analyses, there are also general overviews providing a narrative assessment of SC research in all its subcategories and variations. Cocchia (2014) offers a list of different concepts and definitions in the field of future-oriented urban planning and development by number and origin of the respective studies suggesting that the different concepts are closely related, but show certain temporal and geographical divergences. Besides that, Trindade et al. (2017) show the scientific development of the concepts of the 'smart city' and the 'sustainable city' in recent years connected to possible similarities and linkages among the concepts. Building on this, Fu, Zhang (2017) reinterpret the various concepts in the field of urban development as partial variants of the overarching concept of the 'smart city' and show the evolution of the entire field of research since its origin in the 1980s. In contrast to this view of practical design, Meijer and Bolívar (2016) separate approaches that mainly focus on the installation of a technological infrastructure from those that foster new forms of human partnership in

cities and argue for a comprehensive view on the latter. Kummitha and Crutzen (2017) extend this debate to the entire field of research and distinguish between the 'technological-driven method' (TDM) and the 'human-driven method' (HDM). However, the authors state in agreement with the previous work that the TDM is now on the retreat after its hype in the 2000s and that the HDM is moving more and more into the focus of science. This paradigm shift can be observed in many literature analyses across all topics (Fu and Zhang 2017; Kummitha and Crutzen 2017; Trindade et al. 2017; Tranos and Gertner 2012). Due to the specialization and fragmentation of the field of research mentioned above, however, it is difficult to make general statements because the individual literature reviews taken together form a broad array of SC topics. Although some contributions concern an ex-post perspective (e.g. success factors, challenges or design of SCs), the main debate among scientists tends towards an ex-ante perspective, i.e. towards standardization of the various partial approaches and determination of the methodological school of thought (cf. Fu and Zhang 2017; Kummitha and Crutzen 2017; Trindade et al. 2017).

STUDYING SMART CITIES: CURRENT STATE AND FUTURE RESEARCH DIRECTIONS

In order to ascertain the current state of research, to illustrate scientific progress and to show current research trends, a quantitative cumulation of the various studies is necessary in addition to the qualitative investigation of the research results by means of literature reviews. In contrast to identifying research topics and illustrating the main scientific debate in a qualitative survey, a quantitative survey of the state of research deals with the question (1) which of these identified research topics dominate the field, (2) whether a consensus exists and (3) which topics have received little or no attention so far. In addition, a quantitative analysis of the research field determines the thematic and scientific orientation of a research field as well as identifies avenues for further research endeavors.

Empirical literature is best suited for such a characterization of research, since it specifies the object of study and operationalizes the associated scientific approach. These criteria can be used to determine whether scientific progress in the field either depends on direct observations and field studies (exploratory focus) or evolves by confirmation and further development of scientific theories (confirmatory focus). In addition, empirical research gives insight into the general direction of research questions within a particular field of research. If qualitative studies predominate, research is mainly concerned with the definition, differentiation and delimitation of the object of study, whereas a predominance of qualitative studies indicates research into causal relationships and influencing factors. Consequently, the ensuing section investigates empirical SC literature first in order to characterize the field of SC research and identify its main course of scientific activity.

After having identified the characteristics of the current state of SC research, the analysis turns towards a quantitative analysis of the whole body of SC literature. This provides insights into the major issues in the field as well as into their current scientific progress. Furthermore, the quantitative analysis of citation counts of the respective literature allows for identifying those issues that remain under-researched and state promising directions for further research. To achieve this, the section continues with a quantitative analyse of SC publication figures and citation counts.

Investigation of Methodology and Research Approaches in Empirical SC Studies

With regard to the methodology of empirical research, corresponding studies can be either quantitative or qualitative. In particular, quantitative studies are those studies that initially establish a relationship between the variables to be examined through the research question or that predict a possible result of data evaluation through a hypothesis. The answer to the question or verification of the hypothesis is then given by the present data set using univariate or multivariate statistical methods (Creswell and Plano Clark 2011). Qualitative studies, on the other hand, refer to open questions about 'what' or 'how' and thus to the investigation of a key problem. In the course of the study, further sub-questions emerge from the central question based on the codification of data sets, the categorization and naming of subgroups, as well as the assignment of the codified data to the respective subgroups (Creswell and Plano Clark 2011). Based on a full-text screening of the 103 articles that show an empirical direction of thought, we identify an equal division of the field into equal parts, i.e. 50 studies following a qualitative directive and 53 studies following a quantitative directive.

These results presented in Table 3 show that almost a third of the empirical studies examined in this literature review relies on surveys of different stakeholders involved into a SC project. Other currently important sources of knowledge are content analyses (26 studies), secondary data analyses (20 studies) and observations (17 studies). However, experiments and testing, on the other hand, are rather sparse. This distribution of data collection methodology is typical for a social science research discipline in which the possibilities for experimental research are severely limited by the nature of the issue or the ethical reprehensibility of human experiments. In such cases, science must therefore revert more to the evaluation of historical values (secondary data analysis) or to surveys in order to achieve robust results.

Table 3: Methodology of Empirical Studies on Smart City

Main Research Methodology	**Method of data aquisition**						**Total**	**Percentage**
	Survey	Observation	Experiment	Content analysis	Test	Secondary data analysis		
Quantitative Study	18	6	5	3	0	20	53	51%
Qualitative Study	14	11	1	23	1	0	50	49%
Total	**32**	**17**	**6**	**26**	**1**	**20**	**103**	**100%**

In fact, the high number of surveys in quantitative research (18 studies) is unusual compared to qualitative surveys (14 studies). Qualitative surveys usually form the preliminary methodological stage for quantitative evaluations of interviews. Thus, in a young field of research such as SC, the number of studies based on qualitative interviews should exceed the number of studies based on quantitative methodology. This flaw limits the explanatory power of the results of the quantitative surveys because they lack the methodological

preparatory work of qualitative research. However, it should be noted that qualitative research also draws many results from the contents of project descriptions and political guidelines of SC projects.

Another important aspect revealed by Table 3 is the distribution of the data collection methodology of qualitative studies. While quantitative studies show the typical distribution in methodology, i.e. surveys and secondary data analysis, the distribution of the qualitative methodology is atypical. In the present case of Table 3, the surveys and observations mostly used for qualitative research are underrepresented accounting for a half of the qualitative studies (25 studies). This indicates that the development of SCs is still in its infancy and that surveys can only be carried out among experts. This also explains the low number of observations; since the SC concept as an isolated solution for certain cities has so far lacked a broad basis of objects for observational studies (e.g. comparative studies, development studies, etc.).

Because of these observations, the research field of SCs shows an atypical division of quantitative and qualitative research for a young research field. Usually, a new dynamic research field shows a high number of qualitative studies before the number of quantitative studies gradually increases. In the present case, however, described by Table 3, the reciprocal picture of a dominance of quantitative studies in a young field of research emerges. The described structure of the methodology does not provide any explanation for this phenomenon, so that we have to fall back on other criteria of the literature evaluation.

To investigate the cause of the prevailing dominance of quantitative studies in SC research any further, we proceed with the evaluation of the research design. In empirical research, there are two different options for the alignment of a research project: the exploratory and the confirmatory approach. In case of an exploratory study, the research issue does not rely on any theory, and the connection between the collected data is based either on earlier observations or on logical considerations. Through the collection and evaluation of the data, as well as the linking of variables to dependencies, the respective research work determines dependencies and ‘explores’ the basis for new theories. A field of research with a high number of exploratory studies thus either refers to a young field of research in which the connections between the central variables are still largely unknown and a fundamental theory has not yet been developed, or indicates a paradigm shift within an established field of research.

Confirmatory research, on the other hand, has a solid theoretical basis. Their task is to either verify or falsify existing theories by means of a hypothesis test. A large number of confirmatory studies are usually carried out in established research fields. Assessment of a field of research based solely and exclusively on the amount of confirmatory research, however, is ambivalent because it exists in young and dynamic research fields such as SC, if a consensus has to be reached between several theories, as well as in established research fields, if doubts arise regarding the validity of the existing theories. Table 4 shows the classification of the literature into explorative and confirmatory research approaches according to the line of thought combined with methodological classification.

Table 4: Directions of Thought in Empirical Research on Smart City

Main Direction of Thought	Method of data aquisition						Total	Percentage
	Survey	Observation	Experiment	Content analysis	Test	Secondary data analysis		
Exploratory Studies	21	12	5	17	1	7	63	61%
Confirmatory Studies	11	5	1	9	0	13	40	39%
Total	**32**	**17**	**6**	**26**	**1**	**20**	**103**	**100%**

In line with our previous statements from Table 3 is the distribution of the methodological survey instruments between the two scientific schools of thought. While explorative studies are mainly based on surveys (21 studies), content analysis and observations (12 studies), confirmatory studies mainly draw their results from secondary data analyses (13 studies) and content analyses (14 studies). The comparably high number of confirmatory studies in a young, dynamic field such as SC research is surprising. Against the background of the strong increase in research contributions since 2008, exploratory studies are expected to outweigh confirmatory studies by far but in fact exploratory studies only slightly outweigh them in numbers.

In summary, it can be noted that a balanced pattern of scientific directions of thought may be observed when considering empirical SC research, on the one hand, as well as a balanced pattern of methodological approaches, on the other. This balance is atypical for a young field of research such as SC that experienced its rebirth in 2008. The absence of a hegemony of exploratory and qualitative research can be explained by the fragmentation of the main field into different autonomous sub-areas. The lack of consensus on a general concept for a SC (Trindade et al. 2017; Meijer and Bolívar 2016; Gil-Garcia et al. 2015; Tranos and Gertner 2012) leads to a multitude of divergent concepts from different research disciplines (Lara et al. 2016; Jong et al. 2015; Cocchia 2014; Lee et al. 2014). The various research approaches and theoretical concepts require empirical verification or falsification calling for a strong confirmatory SC research area. Since confirmatory studies are mostly based on quantitative methods, the comparatively high number of quantitative contributions, which can be observed in Table 3, is due to the high research activity in the confirmatory branch of SC studies.

Quantification of SC Research Activity and Implications for Further Research

For the purpose of a thematic focus, the data set of the conceptual literature shown in Table 1 with its total of 212 articles is used for further examination of the research topics. The analysis of the conceptual literature thus offers the opportunity to identify and name areas of high research activity as well as research gaps with only few contributions.

For this purpose, we examined the titles, abstracts and keywords of the 212 articles mentioned above in order to enable a classification of the research landscape into subject areas. On this basis, a total of nine topic clusters could be identified: (1) definitions and

components, (2) urban governance, (3) digital infrastructure, (4) urban planning, (5) urban development, (6) stakeholder interaction, (7) evaluation and reporting, (8) technology acceptance, (9) human resources. Afterwards, we used this clustering method in order to assign the remaining body of empirical literature to these nine topics. Table 5 shows the results of the allocation of the literature to the corresponding thematic clusters numerically and displays the relationship between conceptual, exploratory and confirmatory research for the field of SC.

The order of the subject areas in Table 5 is based on the total number of articles assigned in the penultimate column. This arrangement implies that the areas 'urban governance' (58 articles), 'definitions and components' (51 articles) and 'digital infrastructure' (46 articles) are the most strongly represented in the examined literature. Their high proportion of conceptual studies characterizes these three subject areas in particular, while the empirical contributions represent a much smaller part of the topic-specific literature.

In order to present and quantify the empirical coverage of the conceptual literature, the ratio of the number of empirical studies to the number of conceptual studies is stated in column five. In this instance, a quotient smaller than one indicates an overweight of conceptual studies and a demand for empirical evidence. A quotient equal to one indicates that empirical and conceptual research in this area are in balance. The situation of a quotient greater than one is ambivalent and depends on the number of conceptual studies. If the number of conceptual studies is low, this means that the research field lacks the conceptual basis, but empiricism determines its relevance. This results in a demand for theoretical model developments. Accordingly, the fields of 'technology acceptance' and 'human resources' show a need for conceptual and explorative basic research before empirical validation can be provided by confirmatory studies.

Table 5: Evaluation according to Topic and Scientific Orientation

Topic	Conceptual Studies	Empirical Studies				Empirical Coverage	Total	Percentage
		Exploratory Studies	Exploratory Coverage	Confirmatory Studies	Confirmatory Coverage			
Urban Governance	39	17	0.44	2	0.05	0.49	**58**	**18.41%**
Definitions and Components	41	6	0.15	4	0.10	0.25	**51**	**16.19%**
Digital Infrastructure	38	4	0.11	4	0.11	0.22	**46**	**14.60%**
Urban Planning	26	8	0.31	6	0.23	0.54	**40**	**12.70%**
Urban Development	21	10	0.48	6	0.29	0.77	**37**	**11.75%**
Stakeholder Interaction	21	7	0.33	2	0.10	0.43	**30**	**9.52%**
Evaluation and Reporting	18	4	0.22	7	0.39	0.61	**29**	**9.21%**
Technology Acceptance	5	4	0.80	7	1.40	2.20	**16**	**5.08%**
Human Resources	3	3	1.00	2	0.67	1.67	**8**	**2.54%**
Total	**212**	**63**	0.30	**40**	0.19	**0.49**	**315**	**100.00%**

The other subject areas show the dominance of conceptual research already mentioned. While the topics 'digital infrastructure' and 'definitions and components' have the lowest empirical coverage with 0.22 and 0.25 respectively indicating a great need for empirical research in general, the other areas also show clear deficits. Although 'urban governance', ‘urban planning’, 'urban development' as well as ‘stakeholder interaction’ show a comparably higher empirical coverage ranging between 0.43 and 0.77 respectively, empirical research in these fields is mostly exploratory in its nature represented by exploratory coverage rates that exceed those of the confirmatory type. Thus, we observe a deficit in the availability of confirmatory studies stating great need for research in this branch.While the remaining subject areas also show a clear dominance of conceptual literature and a necessity for further empirical research on SCs, the areas 'technology acceptance' as well as 'human resources' clearly stand out from the others. For these two cases, there exists a predominance of empirical research due to the predominant confirmation of existing SC indices. While data for ‘technology acceptance’ depicts a lack in explorative-empirical studies, the pattern for ‘human resources’ shows a shortage of confirmatory research.

In addition to purely quantitative considerations, scientific impact and relevance are also decisive for a comprehensive picture of the state of research. In order to take this condition into account and to maintain consistency with other meta-analyses, we supplement our quantitative investigation of the literature by the use of Google Scholar Citation (GSC) data. Thus, every single article of the set of 315 empirical and conceptual studies had been searched for using the Google Scholar search engine. After the engine had found the article, the respective citation count, that tallies the number of articles citing the respective study, was added to our literature data base. Taking the GSC into account allows

for a benchmark of the acknowledgement of a publication within the scientific literature. Table 6 gives an overview of the aggregated GSC results for each of the clusters mentioned above.

Due to the distortion effect caused by varying publication periods, we use average GSC scores adjusting for this temporal bias in citation counts. Thus, the GSC count of a publication was divided by the age of the article in years in order to obtain a measure for the average citations per year. Based on this temporal adjustment, it is possible to compare the various areas of research with regard to their scientific significance and impact.

Table 6: Google Scholar Citation Cluster Analysis

Topic	Sum of Average GSC per Year	Sum of Average GSC per Year in %	Number of Publications	Number of Publications In %	Sum of Average GSC per Year / Number of Publications
Urban Governance	508.88	12.62%	58	17.41%	8.77
Definitions and Components	1,416.30	35.14%	51	17.41%	27.77
Digital Infrastructure	450.53	11.18%	46	15.51%	9.79
Urban Planning	477.68	11.85%	40	13.92%	11.94
Urban Development	357.11	8.86%	37	11.07%	9.65
Stakeholder Interaction	349.65	8.67%	30	9.49%	11.66
Evaluation and Reporting	198.06	4.91%	29	7.59%	6.83
Technology Acceptance	104.00	2.58%	16	5.70%	6.50
Human Resources	46.00	1.14%	8	1.90%	5.75
Total	**4,030.77**	**100.00%**	**315**	**100.00%**	**12.80**

As indicated by the highest frequency of citations among all identified research topics, i.e. 27.77 citations per publication, it holds that research regarding ‘definitions and components’ is attached a great importance by SC researchers. There is also a high research relevance for the topics of ’urban planning’ (11.94 citations per publication for 40 publications) and 'stakeholder interaction' (11.66 citations per publication for 30 publications). As a result, the mentioned subject areas are very relevant to SC research, which reflects in high citation figures. Combined with the relative low number of publications, these fields of SC topics are thus underrepresented and further research tackling these issues is expected to have a major impact.

On the other hand, the less pronounced subject areas 'urban governance' (8.77 citations per publication for 58 publications), 'digital infrastructure' (9.79 citations per publication

for 46 publications) and 'urban development' (9.65 citations per publication for 37 publications) indicate that the individual research projects for the respective field of research receive less attention. In view of comparatively high numbers of publications in these thematic clusters, the research topics mentioned appear to be over-researched in the literature to date.

DISCUSSION AND CONCLUSIONS

By investigating the evolution of the field of SC research, we observe that the steep rise of SC research after the year 2008 has led to a scattered field with few opportunities for unifying the various constructs into a comprehensive approach. Thus, the fragmented research environment has created demand for inclusive, conceptual studies to achieve a consensus among the different sciences involved in SC theory development.

Second, the investigation considering the proportion of quantitative and qualitative research shows that quantitative research relies heavily upon the analysis of content and scope of SC projects concerning practical implementation. Thus, quantitative-empirical research is rather based on field research than on experimental or laboratory research. Due to the hegemony of quantitative-empirical research and the constantly changing demands on the fledgling concept of SC, there exists a need for qualitative survey among SC experts to explore and shape new constructs for SC management.

Third, with regard to the orientation of scientific contributions, the literature examination reveals a balanced pattern among exploratory and confirmatory research. A predominance of exploratory research is expected to prevail, but, due to the above-mentioned fragmentation of SC and the range of small-scale concepts in the field, the extent of confirmatory research is quite large. This results in an increased demand for exploratory-empirical SC research.

Fourth, the relationship between empirical and conceptual literature - i.e. the empirical coverage - can be used to determine the need for research concerning a particular research topic. In order to obtain a better overview, we presented the empirical coverage in Table 6 for the thematic clusters as well as the branches of SC research. By using a coverage ratio for exploratory and confirmatory empirical research, we identify a need for exploratory research in seven of nine thematic clusters. Demand for confirmatory research is even higher pertaining to eight thematic clusters. In contrast, the smallest clusters ‘technology acceptance’ and ‘human resources’ still need a conceptual foundation and thus require more conceptual research in the future.

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Fifth, when taking the scientific impact of the different subject areas included in SC research into account, the pattern of significance determined by citation counts reveals topics that are underrepresented by current research such as ‘definitions and components’, ‘urban planning’ as well as ‘stakeholder interaction’, while others are overrepresented by current research such as ‘urban governance’, ‘digital infrastructure’ and ‘urban development’.

Looking at the field of SC research as a whole, there is a very high need for research in the field of explorative empirical studies. This finding has already become clear in the previous sections and is particularly attributable to the novelty of SC research. Since a large number of conceptual contributions already exist in the areas of 'definitions and components', 'urban governance' and 'digital infrastructure', qualitative explorative-empirical research is the next obvious step to improve and extend the existing constructs by means of surveys and observations before they can be falsified by means of confirmative-empirical research contributions.

The main objective of this study was to present and evaluate the state of SC research and to outline the research landscape. With the help of the results of previous literature reviews, a first impression of the conditions and research tendencies emerged, which provided a frame for the subsequent evaluation of the literature database. It was found that research on SCs really gained momentum in 2008 and experienced a steep ascent in importance in the subsequent years. However, the initial focus on computer technology led to specific application-oriented research aimed at individual solutions for specific application areas splintering the whole body of research articles into various loosely connected topics. As a result, an overarching approach, which places the individual sub-areas of a SC in a larger context, developed only hesitantly such that to date there remains a need for further research in the area of conceptual standardization of SC concepts. Due to the patchwork of various research efforts, large differences arise in the empirical coverage and theoretical elaboration of the individual topics.

This patchwork of different research approaches from different branches of science can also be found in other literature reviews (cf. Fu and Zhang 2017; Cocchia 2014). Especially Fu and Zhang (2017) highlight in their review this dispersion of research approaches by presenting a total of ten different urban development concepts and their evolution over time. The authors argue that “[t]hese concepts form a complex web with each having its own distinctive characteristics” (Fu and Zhang 2017, p. 113). Our findings concerning the different topics of SC research confirm this argument, but in contrast, our approach does not consider the individual concepts as self-contained branches of science, but as sub-areas of the overarching 'smart city' concept. On that note, we follow the line of thought of Cocchia (2014) that summarizes the various sub-areas under the label of SCs. In line with these considerations are Öberg et al. (2017) stating that “[t]he city being ‘smart’ means that the actors as multiple stakeholders (or societal initiatives guiding these actors) aim for sustainable solutions adopting digitalisation and other technological advancements” (Öberg et al. 2017, p. 470).

With regard to the individual sub-concepts of SC, the concept of 'sustainable city' emerges in the foreground. This is mainly due to the fact that the concept of 'urban sustainability'

dominated the urban development debate until 2007 (Fu, Zhang 2017) and was subsequently replaced by the SC concept due to technological progress in ICT. However, the literature disagrees on whether the concept of the 'sustainable city' can be seen as a subdivision of the SC. While holistic approaches argue for incorporating the concept of 'urban sustainability' as a policy and implementation directive for SC solutions (Trindade et al. 2017; Cocchia 2014), the main literature in the field has not yet explicitly connected itself to SC research (cf. for this argument Hamman et al. 2017; Petit-Boix et al. 2017).

In view of the integration of the 'sustainable city' concept into the SC approach, Trindade et al. (2017) state that further research should explore whether sustainability might be successfully anchored within a SC environment as well as how the establishment of a sustainable doctrine is achieved within a SC solution. In conjunction, "there is ultimately no single or absolutely prevailing model of 'sustainability' or the 'sustainable city'" (Hamman et al. 2017, p. 353). There is thus a demand for conceptual and explorative empirical literature on the themes of 'urban governance', 'urban planning' and 'urban development'. The interpretation of the results with regard to the empirical coverage of the issues is in line with this finding although our analysis indicates that the impact of further research is limited.

This also holds true if the whole landscape of SC research is examined in detail. Kummitha and Crutzen (2017) discover during their literature review that although SC face an increased popularity among scholars, there exists no agreement on its definition and scope. Henceforth, the authors argue for more exploratory studies that examine the emergence of SCs from the practical side in SC projects. Fu and Zhang (2017) argue that SC "has to break the boundaries of traditional urban sustainability discourse and probe into various other aspects […] to explore the new possibilities that information technologies can engender" (Fu and Zhang 2017, p. 122), thus claiming for more exploratory research in the field of 'digital infrastructure' as well as 'concepts and components'.

In terms of methodology and results, this meta-study provides several contributions to the current state of research. First, the interdisciplinary consideration of the various subject areas creates a holistic picture of SC research and, as required by previous research, places the specialized questions in a superordinate context. Second, a thorough examination of the research intention and direction of thought shows the trends that exist in the respective field of research, the topics research has dealt with in detail and the issues that received little attention so far. Third, the quantitative evaluation of citations shows which research areas are currently the subject of intense discussion in the literature, i.e. where the research foci lie. Fourth, the form of the research landscape are determined on the basis of the trend and quantity of research such that a profile of research needs may be derived.

For our literature evaluation, we limited the selection to English peer-reviewed journal articles only. However, this procedure is restrictive as it excludes possible research in other languages from the study. Since the study is a structural analysis of the research field on SC, which examines prevailing schools of thought and research trends, it is reasonable to assume that the exclusion only affects the statements regarding the scope, but not the results regarding the structure and orientation of SC research.

A further critical aspect is the thematic delimitation. Sorting out technical literature distorts the picture of digital infrastructure literature by removing technically relevant literature from the analysis. This criticism can be countered by the fact that the evaluation carried out here refers to concepts and ideas which encompass different technical solutions and are combined in a larger system. The individual technical component appears as a cogwheel of a larger technical system whose technical functionality and composition is of secondary interest. Despite careful evaluation of the literature, it cannot be ruled out that this clustering may have led to relevant literature being sorted out for further evaluation.

Clustering by topic and orientation of the research contributions was also difficult to handle. Some studies dealt with several subjects simultaneously and showed both empirical and conceptual elements. However, in order to ensure a clearly delineated classification, we selected a focus topic from the topics dealt with and examined whether the empirical or conceptual part of the study predominated. Although a large part of the classification was thus based on objective criteria, the classification of these borderline cases is based on the authors' subjective assessment. However, since these borderline cases comprise less than 10% of the sample, this influence of the subjective assessments on the overall result is negligible.

Finally, a comprehensive summary of previous research by its nature is associated with a loss of information due to summation and clustering although the method is necessary to provide a comprehensive view upon the state of the art. Therefore, we are confident that the insights gained through the overarching view on the various parts of SC research compensate the information loss due to our methodology. In view of the results of the literature evaluation and those of previous reviews, it can be stated that SC is a widely ramified field of research with very independent sub-areas. As highlighted several times in the previous sections, future research should aim at harmonizing research approaches and overcoming the boundaries between different sub-sectors, such as the sustainability debate. Possible research questions in this context would be: 'How is the field of sustainability anchored in ongoing SC projects?' or 'How can the various concepts of the 'sustainable city', the 'eco city', the 'green city', the 'information city', the 'knowledge city', the 'ubiquitous city' and the 'livable city' be fully integrated into an overarching SC concept?

In addition, the practical design and implementation of SC solutions in urban environments raises the question of how residents face the new concept of their city. Since this area is still underrepresented in research, the theoretical question of how citizens are integrated into the system of a SC (stakeholder interaction) and how they react to changes in the urban environment arises. Consequently, these issues require further conceptual research in order to provide theories and constructs for subsequent confirmatory empirical research. Research questions would therefore be which participation channels a SC can provide for its citizens under which circumstances or which success factors favor the public acceptance of a SC project.

NOTES

[1] Title, abstract and keyword search using ‘smart city’ / ‘smart cities’ / ‘smart government’.

[2] Terms related to SC: ‘digital city’ / ‘knowledge city’ / ‘intelligent city’ / ‘sustainable city’ / ‘ubiquitous city’

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