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Classifying Smart City Startups: The Smart City Index

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Abstract
In this paper we present an index for coding new ventures, projects and firms as "smart-city" or not. The index is based on a systematic assessment of some 70+ definitions of the concept from the literature. Based on this analysis, we propose a 7-item coding scheme based on venture descriptions that are commonly available from public data sources. We identified two necessary and 5 "intensity" items and propose an algorithm that translates these items into a single smartc-city index (SCI) that expresses the degree to which an activity is contributing to smart city development in a score between 1 and 5. We then show the results of coding 759 new ventures in different datasets to illustrate that our index gives sensible results. Some 90 (11%) of these ventures could be classified as "smart city" in our sample, scoring an average of about 3.3, with significant variation around these averages that make intuitive sense. Our index can be used in a broad range of applications.

Keywords: Urban Development; Smart City; Entrepreneurship; Innovation; Data Collection

JEL classification: C81, L26, O33, Q55

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1. Introduction

Smart city development is high on the policy agenda of urban planners around the world (de Lima et al., 2020). Research has shown that smart cities are part of a new and rapidly changing reality that will affect the efficiency, equity, sustainability, and quality of life in cities (Batty et al., 2012). Consequently, the concept is increasingly being researched, also in the academic literature (e.g. Tan, 1999; Stolfi & Sussman, 2001; Sproull & Patterson, 2004; Sun & Poole, 2010; Fietkiewicx et al., 2017; Ismagilova et al., 2019; Krisna Adiyarta, 2020). However, the literature is currently developing without a clear and unambiguous definition of the concept. This hampers the collection of qualitative and quantitative data that is comparable across papers and essential in developing theory and testing the corresponding hypotheses. It is essential to have a clear and empirically implementable definition of the concept.

In this paper, we develop a workable definition of the concept "smart city" based on 73 definitions found in 93 academic articles. In this emerging literature, we also found 20 literature review articles. Based on the most common elements in these definitions we develop a simple coding or scoring scheme and combine these in a simple algorithm. The coding scheme plus algorithm allow us to quickly classify, e.g. projects and startups as being "smart city". We develop this classification scheme following the methodology developed for the definition of "user innovations" in Eckinger and Sanders (2019). These authors classified their concept in two steps. After collecting a wide variety of definitions from the literature, they first identified the essential elements common to all interpretations. These essential elements in our case, make up the necessary conditions for being defined as a smart city project (0/1). We then code and count additional elements and take the eight most common ones. Scoring projects and startups on each of these (0/1) and multiplying the sum of these (plus 1) times the necessary condition score, gives us our Smart City Index (SCI) intensity score (1-6).

The contribution of this paper is, therefore, twofold. First, we collected definitions of smart cities used in the emerging literature, providing an up to date overview of this emerging concept. Second, we adapted the classification method in Eckinger and Sanders (2019) to classify projects and startups as a "smart city" using our smart City Index (SCI). In this way, we will facilitate data collection and future empirical research on smart city development. To illustrate the usefulness of our index we have scored startups in the Nice, Utrecht and Gothenburg ecosystems for the European Horizon2020 project IRIS.

The remainder of the paper is structured as follows. First, we present prior research and summarise the current state of literature in reference to the smart city concept. Second, we present the method used for data collection and coding. Third, we report the results obtained by applying the coding to the three databases of three incubators in IRIS lighthouse cities Utrecht, Gothenburg and Nice. Last, conclude and a discuss the limitations of this paper.

2. Literature review

Although there is a growing interest in smart cities, there is no common definition of this concept. In some research, modern cities are referred to as for example intelligent city, digital city, innovative city or knowledge city (Tan, 1999; Krisna Adiyarta, 2020; Sun & Poole, 2010; Ismagilova et al., 2019; Fietkiewicx et al., 2017; Sproull & Patterson, 2004; Stolfi & Sussman, 2001). These studies all provide building blocks for our understanding of the phenomenon. But when authors collect data, often for a limited number of case-studies, based on their own definitions, this limits the comparability across studies, generalisability of results and the usefulness of these definitions for empirical research. Moreover, "smart cities" represent something more than these more limited concepts (Yigitcanlara et al., 2018; Samarakkody et al., 2019). Definitions of "smart cities", however, also emphasise different themes, elements, or dimensions (e.g. Giffinger et al., 2007: Winkowska, Szpilko, & Pejić, 2019; Silva, Khan & Han, 2018). A highly cited definition of smart city that incorporates many of these elements is "a city is smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and high quality of life, with a wise management of natural resources, through participatory governance" (Caragliu, Del Bo & Nijkamp, 2011, p.70) However, other definitions emphasize other dimensions. For example, according to Zhuhadar et al. (2017, p. 274) "smart cities are those cities that have the greatest quality of life and economic wellbeing for their citizens". This definition emphasizes the citizens in a city and their quality of life. Whereas, e.g. Neirotti et al. (2014, p.25) focus on the Information and Communication Technologies (ICT) aspect of smart cities, stating: "smart cities are characterized by the pervasive use of ICT, which, in various urban domains, help cities make better use of their resources". Governance and institutional components are also often emphasized in definitions. According to for example Nam & Pardo (2011, p.284) "smart cities are an organic connection among technological, human and institutional components. The usage of 'smart' captures innovative and transformative changes driven by new technologies". Most scholars emphasize the quality of life, citizen wellbeing, technology, or governance. But other topics are also frequently incorporated, such as innovation, collaboration, and infrastructures. None of the definitions incorporates all the themes identified in the definitions of smart city.

What all definitions do seem to have in common is the idea that a smart city challenges the old way of doing things in the urban environment. This puts entrepreneurs in focus (Lombardi et al., 2012). However, as there is no readily available definition of smart city, it is even harder to define a smart city start-up. The empirical literature on smart city start-ups is therefore limited to date (REFS). Building on the definitions that have been proposed in the literature, we propose a definition and develop a coding scheme for smart city start-ups to help researchers collect data and do empirical research on smart city development.

3. Methodology

The aim of this paper is to develop a clear classification scheme to identify "smart city" projects and start-ups. To do so, we follow the method proposed in Eckinger and Sanders (2019), using a variety of definitions found in the existing literature. Based on these definitions, we develop an index using on the one hand necessary conditions for "smart city", and on the other hand, some non-necessary variables to measure the intensity. We call this the Smart City Index (SCI). In this section, we explain how we get to this index.

First, we systematically collected papers regarding smart cities and their definitions in the literature via Google Scholar. The search terms used were "smart city", "smart-city", "smart city" AND "literature review", "smart city" AND "definition", and "definition smart city". In total, we came up with 165 articles, including multiples of the same reference and twenty literature review articles from which we took articles and definitions to supplement our reference list. After deleting the recurring papers, we were left with a list of 92 unique peer-reviewed papers, including 20 literature reviews (see Appendix A). These references were collected in an Excel file with a column for the author, publication date, title, and journal (Appendix B). Next, these articles were ranked by the number of citations per paper. We took citations in Google Scholar on the 1st of April 2020 and added this to the spreadsheet in a separate column. To be more accurate, two extra columns were added; one with citations per year, thus taking the total citations per article and dividing it by the years the article had been in circulation, and another for the rounded-up number of these citations per year. We deleted articles below 3 citations per year, however keeping the articles of 2019 and 2020 regardless, plus the definitions of the European Parliament (2014). Finally, we ended up with 78 different references.

Next, we divided the 78 articles amongst ourselves (excluding the literature reviews) and looked in each one for a definition using "smart city", "define" and/or "definition", later adding this to the Excel file in a new column. Some definitions were quoted multiple times by different authors. These were deleted, after which we ended up with a total of 73 unique definitions of a smart city in our Excel sheet (See Appendix B). We then listed the main keywords per definition. To come to an idea on what keywords appeared most, we did an initial search of the recurrence per word. Based on this, we were able to code the most recurring keywords and chose the following themes, coded 0 if the definition did not include the theme, coded 1 if it did. The themes were "technology", "ICT", "quality of life", "city", "sustainability", "innovation", "collaboration", "citizen", "integration", "economic", "human capital", "social capital", "business", "resource management", "infrastructure", "efficiency", "safety/security", "transportation", "network", "energy", "growth", and "creativity". Next, we calculated the percentage of appearances in the 73 definitions by making a sum of all the codes and ordered them in descending order (see Appendix C1). Additionally, we also

calculated the percentage of appearances based on the total amount of citations per year (see Appendix C2).

3.1 First design

Based on these percentages, we identified the themes and keywords in Table 1. In this table, we present the themes and keywords that are included in the particular theme. From the first results, we defined two necessary conditions - technology and city - and seven intensity conditions - ICT, citizen, environmental sustainability, quality of life, social capital, economic and human capital.

Table 1: SCI

Conditions	Themes	Keywords included
Necessary conditions	Technology	Technology, data, sensors, activators, internet, ICT, IT, database, algorithm, grid, digital, solar panels, smart meters, WIFI, software, hardware, smart devices)
	City	City, urban, urban challenges, territory, place, geographical area
Intensity conditions	ICT	ICT
	Citizen	Citizen, inhabitants, people
	Environmental sustainability	Sustainability, green, environmental, ecological
	Quality of Life	Quality of life, liveability, prosperity, habitable, well-being
	Social Capital	Social capital, social, social wealth, inclusion, community
	Economic	Economic
	Human capital	Human capital, intelligence, skilled workers/jobs, (high) education, knowledge

Based on these first results, multiple robustness tests are carried out. In these robustness tests, our first results of the coding scheme are put into practice on the data retrieved on the start-ups in incubators in Utrecht, Gothenburg and Nice. Each author individually coded the start-ups, based on their description. These descriptions were taken from the company or incubator websites (see Hermse, 2020; Nijland, 2020 and Picari, 2020 for details on the collection of these qualitative data). In most cases, the information gathered was sufficient to be able to code the themes. The results of this first coding were discussed among the authors. This way, we cross-referenced our coding and validated our coding scheme. We gather information on whether the coding scheme is replicable, and

whether it is even possible to code each of the variables. Some small changes were made to the coding scheme according to the results of the robustness tests.

3.2 Practical applicability

To test our coding scheme, we coded several datasets independently and iterated the coding scheme accordingly. First, we applied the above coding scheme to the start-ups in a dataset of start-ups that have applied for incubation at UtrechtInc between 2014 and 2017. For each start-up, we coded all start-ups, with three people independently, on the nine variables - two necessary and seven intensity conditions - using the descriptions of the start-ups provided by Eveleens et al. (2019). These rather elaborate descriptions were composed from information collected online, using LinkedIn and the incubator files (see Eveleens et al., 2019 for details on the data collection). In the discussion of individual results, small irregularities were found. We therefore decided to make a few adjustments.

First, for the themes of human and social capital, we follow Laroche et al. (1999, p.89), and defined human capital as the "aggregation of the innate abilities and the knowledge and skills that individuals acquire and develop throughout their lifetime". Thus, the theme of human capital has to do with the attraction and appeal to skilled labour forces in the context of smart city. Therefore, we clustered the keywords "intelligence", "skilled jobs", "(high) education" and "knowledge" under this theme. Stated in Hollands (2008), human capital also has to do with "creativity". Following Healy and Côté (2001, p.41) we defined social capital as "networks together with shared norms, values and understandings that facilitate co-operation within or among groups". Social capital entails various keywords from our definitions, namely, "social", "social wealth", "inclusion" and "community". Important as both concepts are for a smart city, however, we were not able to code these variables consistently, based on the descriptions of companies we looked at. Acquiring values for these variables in large datasets would therefore be unpractical and unfeasible and we decided to take them out of our intensity factors for now. We discuss them, nevertheless, because, should this problem be resolved somehow, future research could easily add them to our SCI.

Second, the definitions of the themes "quality of life" and "citizens" needed some more precision. Finally, we decided to adjust the theme "sustainability". A company should not only be seen as sustainable if the products and services offered are sustainable but also if the general goal of the company is to contribute to sustainability. An example here is the website Nature Today. The website is not sustainable in itself, however, the information they spread increases awareness of nature and of what needs to be preserved.

After making these adjustments in the first iteration, we tested our adapted coding scheme in a second dataset. This time, we used a dataset of start-ups in Gothenburg. These start-ups are incubated at Chalmers Ventures between 2015

and 2020. Three authors coded ten companies independently. This time we coded them on seven variables - two necessary conditions and five intensity conditions. The descriptions of the companies on the Chalmers Ventures website, however, are fairly short and basic. This made the coding of the start-ups more challenging, but we managed to get quite similar results. In our discussion, we decided to code the variable "quality of life" 1 only when the start-up has a direct effect on the quality of life of people. Incorporating the indirect effects on the quality of life in this variable would introduce a lot of ambiguity and subjectivity, which would make it hard for others to replicate the coding. Additionally, it became clear in the discussion that the definition of "technology" should be considered a lot broader than some may have in mind. Therefore, before coding, it is important that one has a good and common understanding of what "technology" actually entails. This allows for a more accurate replication when using the algorithm.

We then coded a second set of start-ups in Gothenburg. We used twelve start-ups to check our adapted coding scheme. The results we individually obtained were very similar, with only a few discrepancies. This means that the coding scheme is more or less replicable and the definitions were no longer ambiguous. When discussing the results, we agreed that to be able to code the variable "technology" as 1, new academic knowledge or R&D should be put into practice by the start-up. We acknowledge that this makes technology time dependent, which may introduce some ambiguity. However, we feel it is the most reliable way of coding technology, since it is closest to the definition. This means that the technology a start-up uses, should be based on new knowledge, or academic research. Besides that, it proved challenging to code the variable ICT. We agreed that a start-up should be able to collect, store, use and send or share data electronically (ICT, n.d.) to be coded 1 on this variable.

Another discussion we had was about the variable "economy". After having coded another 12 start-ups independently, we agreed that "economics" should entail both the direct effect on the start-up itself, for example cost reduction, but also the indirect effects on the customers of the start-up. These customers can be businesses or consumers, so it is valid for both B2B and B2C start-ups. In contrast, we decided to code the variable "quality of life" as 1 only when the effect of the start-up on the quality of life is direct. The indirect effect on the quality of life is more prone to interpretation, which would limit the replicability of our coding scheme. Finally, we agreed that the variable "citizens" should be coded a 1 when we are also able to code the variable "city" as 1, as these two variables are connected to each other.

With these iterations, we were able to proceed and code the full datasets for the Netherlands (a further 194 start-ups various Dutch cities; see Hermse, 2020 for details on the data) in Gothenburg (157 start-ups in Chalmers Ventures; see Nijland, 2020 for details on the data) and Nice (295 start-ups in incubator PACA-

EST; see Morin, 2019 and Picari, 2020 for details on the data). The results of our coding are presented and described in section 4.

4. Results

Based on the keywords and the percentages of how many times they were present, unweighted and weighted with the number of citations, we identified two necessary conditions and various intensity conditions. With some iterations, we developed our final coding scheme to be practical and empirically useful. The necessary conditions that have to be met for a start-up to be defined as a "smart city" start-up and our SCI to have a value above 0 are "technology" and "city". We define these themes a follows:

- **Technology**. Defined as "the use of scientific knowledge or processes in business, industry and manufacturing" (Cambridge dictionary, 2020). Technology is the umbrella term for various terms that can be present for a smart city start-up. Some examples of these keywords included in the theme technology are "database", "solution", "operating system", "sensors" and "algorithm".
- **City**. The city is defined as an urban challenge and "it outlines how the humanitarian community is adapting to address the challenges posed by urban areas" (Knox et al., 2012). Defined as an urban challenge, this means that a start-up needs to be working on or creating a solution or service for an urban challenge, to conform to this necessary condition. Some keywords that are used to signal these for the term "city", are "urban challenges", "territory", and "geographical area".

Additionally, we added five remaining intensity factors. As a start-up complies with one or more of the intensity conditions of being a smart city start-up their intensity rating increases. Ultimately, we define "ICT", "citizen", "environmental sustainability", "quality of life" and "economy".

- **ICT** stands for Information and Communication Technology and is defined as "the use of computers and other electronic equipment and systems to collect, store, use, and send or share data electronically" (ICT, n.d.). These technological tools and resources include computers, the Internet (websites, blogs, and emails), live broadcasting technologies (radio, television, and webcasting), recorded broadcasting technologies (podcasting, audio and video players and storage devices) and telephony (fixed or mobile, satellite, visio/video-conferencing, etc.)" as well as computer software and hardware (Unesco, 2020). Some examples that are included in the term "community" and "platform". Important note: as "ICT" is coded as 1, "Technology" also has to be coded as 1, since "ICT" is a part of "Technology".
- **Citizen** includes the keywords "citizen", "inhabitant" and "people". A smart city implpements practices that are beneficial in any way for its inhabitants and should improve their trust in urban institutions (Dameri, 2013). Thus, citzens are the beneficiaries of the solutions that a smart city start-up

offers. Important note: "Citizen" is a condition that can only exist if "City" is coded as 1, thus also fulfilled.

- **Environmental sustainability** is defined according to the definition of Gleeson and Low (2000) and Inoguchi et al. (1999) where environmental sustainability refers to the ecological and 'green' implications of urban growth and development. Some examples of related keywords that flag this topic are "energy", "renewable", "reduce waste", "reduce emissions", "bio" and "LED".
- **Quality of Life** has to do with the improvement of life and wellbeing and making the environment more habitable and liveable for the inhabitants. Economic prosperity is also key to improving the quality of life (Hollands, 2008) but captured separately. To score 1 on this variable, the quality of life needs to be improved directly by the product or service offered by the start-up. Some examples of keywords related to this concept are "help", "health", "simplifies everyday life" and "medical solution".
- **Economy** is defined as the activities of production and consumption of limited resources. This theme, therefore, includes the tackling of economic challenges by using cost reducing, optimization techniques in a sustainable way. These optimization processes in terms of costs should be beneficial for the users. In other words, reduce costs for the businesses and people that buy their product or service. Some examples of keywords to flag this concept are "cost saving", "cheaper", "loss reduction", "cost efficient" and "low cost".

In Table 2 the necessary and intensity conditions are displayed, with the keywords included in each theme. For each condition, start-ups were coded a 0 or 1. After the coding, formula (1) is used to calculate the Smart City Index for that start-up.

*SCI = (technology*city)*(1+ICT +citizen+environmental sustainability+quality of life+economic)*

NC(x) = 0 if not; NC(x) = 1 if yes
IC(x) = 0 if not; IC(x) = 1 if yes

In this formula, all the intensity conditions are equally weighted. Based on formula, start-ups are granted a score between 0 and 6, with the following meaning per score:

0 = At least one of the NCs is = 0
1 = All the NCs, none of the ICs
2 = NCs + (ICT or citizens or environmental sustainability or quality of life or economic)
3 = NCs + MAX 2 (ICT and/or citizens and/or environmental sustainability and/or quality of life and/or economic)

4 = NCs + MAX 3 (ICT and/or citizens and/or environmental sustainability and/or quality of life and/or economic)
5 = NCs + MAX 4 (ICT and/or citizens and/or environmental sustainability and/or quality of life and/or economic)
6 = NCs + MAX 5 (ICT and/or citizens and/or environmental sustainability and/or quality of life and/or economic)

Table 2: Final SCI

Conditions	Themes	Keywords included
Necessary conditions	Technology	Technology, data, sensors, activators, internet, ICT, IT, database, algorithm, grid, digital, solar panels, smart meters, WIFI, software, hardware, smart devices)
	City	City, urban, urban challenges, territory, place, geographical area
Intensity conditions	ICT	ICT
	Citizen	Citizen, inhabitants, people
	Environmental sustainability	Sustainability, green, environmental, ecological
	Quality of Life	Quality of life, liveability, prosperity, habitable, well-being
	Economic	Economic

Tables 3 and 4 below shows the descriptives for our coded data for the samples from incubators (Chalmers, UtrechtInc, Climate-KIC and PACA-Est) and Dutch cities respectively. The samples show that smart city innovation is not uncommon in our datasets. Over all incubators, the percentage of start-ups that could be classified as "smart city" is 11.8%, ranging between some 9% in Gothenburg and 27% in Climate KIC, an incubator dedicated to sustainable innovation. It should also be noted that the most restrictive necessary condition is "city", not "technology", as the latter scores 1 for over 90% in all samples. Of the "intensity" factors, the scores on "citizen" are clearly lowest at on average 5%. Whereas the use of ICT technology is common to some 50% of the sample. All this makes sense intuitively and corresponds with what we would expect given the profiles and nature of the incubators.

Table 3: Descriptives for Incubators

	City	Technology	Quality of Life	Citizen	Sustainability	ICT	Economic	#Smart city	Average SCORE	Obs.
Chalmers Ventures, Gothenburg, SE	14 (8.92%)	149 (94.90%)	34 (21.66%)	5 (3.18%)	33 (21.02%)	97 (61.78%)	41 (26.11%)	14 (8.92%)	3.29	157
UtrechtInc, Utrecht, NL	6 (13.33%)	43 (95.56%)	8 (17.78%)	4 (8.89%)	7 (15.56%)	38 (84.44%)	20 (44.44%)	6 (13.33%)	3.67	45
Climate-KIC, Utrecht, NL	19 (27.94%)	68 (100%)	20 (29.41%)	9 (13.24%)	60 (88.24%)	19 (27.94%)	55 (80.88%)	19 (27.94%)	3.84	68
PACA-Est, Nice, FR	29 (9.8%)	294 (99.6%)	68 (23.1%)	10 (3.4%)	86 (29.2%)	103 (34.9%)	74 (25.1%)	28 (9.4%)	3.21	295
Total	68 (12.0%)	554 (98.0%)	130 (23.0%)	28 (4.9%)	186 (32.9%)	257 (45.5%)	190 (33.6%)	67 (11.8%)	3.34	565

In Table 4 we observe that in a sample of start-ups in different Dutch cities, that the patterns are similar. Some 11% of the start-ups are classified as "smart city" and once more technology is not a very discriminating factor. For this smaller sample it is remarkable that the start-ups coded "1" on citizen do seem to be more common (at about 10% on average with rates as high as 40% in Rotterdam), but the sample sizes differ quite a bit across the cities, with most start-ups concentrated in Amsterdam. For Amsterdam, the pattern is roughly comparable to the sample in UtrechtInc. As that incubator has rather general programs for business incubation, this suggests the smart city index works reasonably well in and outside incubators.

Our complete datafiles, where the ventures have been listed and coded, based on the descriptions provided in the dataset, are available from the authors on request for the purpose of calibrating in coding teams coding new sets of start-ups or firms, provided a data sharing agreement can be negotiated. In this way we hope to build an expanding dataset of coded ventures for future research.

Table 4: Descriptives for Dutch Cities

	City	Technology	Quality of Life	Citizen	Sustainability	ICT	Economic	#Smart city	Observations
Amsterdam	10 (9.2%)	109 (100%)	10 (9.2%)	5 (5.0%)	16 (14.7%)	99 (90.8%)	38 (34.9%)	10 (9.2%)	109 (56.2%)
Rotterdam	6 (20.0%)	30 (100%)	8 (26.7%)	12 (40%)	6 (20%)	21 (70.0%)	9 (30.0%)	6 (20.0%)	30 (15.5%)
Den Haag	0 (0.0%)	13 (100%)	0 (0.0%)	0 (0.0%)	2 (15.4%)	10 (76.9%)	1 (7.7%)	0 (0.0%)	13 (6.7%)
Utrecht	3 (45.8%)	19 (100%)	3 (15.8%)	1 (5.5%)	4 (21.1%)	17 (89.5%)	4 (21.1%)	3 (15.8%)	19 (9.8%)
Eindhoven	2 (33.3%)	6 (100%)	1 (16.7%)	1 (16.7%)	1 (16.7%)	3 (50.0%)	2 (33.3%)	2 (33.3%)	6 (3.1%)
Delft	2 (11.8%)	17 (100%)	4 (23.5%)	2 (11.8%)	6 (35.3%)	12 (70.6%)	6 (35.3%)	2 (11.8%)	17 (8.8%)
Total	23 (11.9%)	194 (100%)	26 (13.4%)	21 (10.8%)	35 (18.0%)	162 (83.5%)	60 (30.9%)	23 (11.9%)	194 (100%)

5. Conclusion

The aim of this paper was to develop a classification scheme for smart city start-ups. We based our working definition on 73 definitions found in the literature. In the literature, there is no common definition of the concept smart city, even though there is a growing interest in the concept. Various terms are used interchangeably with the term "smart city" in the literature, such as digital city or intelligent city (Tan, 1999; Krisna Adiyarta, 2020; Sun & Poole, 2010; Ismagilova et al., 2019; Fietkiewicx et al., 2017; Sproull & Patterson, 2004; Stolfi & Sussman, 2001). The definitions of smart cities are based on different themes, elements and dimensions (Giffinger et al., 2007: Winkowska, Szpilko, & Pejić, 2019; Silva, Khan & Han, 2018). These various elements have been used to create a practical coding scheme. Following the method of Eckinger and Sanders (2019), we listed the main keywords present in each definition of smart city. Based on these keywords, we identified the most recurring keywords and overarching themes. Based on these results, we developed an index with necessary conditions for "smart city" and intensity conditions for "smart city". Ultimately, the results consisted of two necessary conditions - "technology" and "city" - and five intensity conditions - "ICT", "citizen", "environmental sustainability", "quality of life" and "economic". We then tested the coding scheme in actually coding data on start-ups in three European cities and conclude that, even in the case where only limited information on the start-up is available, our coding scheme allows one to quickly code and compute the SCI for start-ups. Being able to do so consistently and unambiguously across multiple datasets and cities can help develop especially the more quantitative empirical analysis of smart city development that is currently still in its infancy. There are of course also limitations to this paper. First, when it comes

to the themes, we defined them in a way that makes sense today. However, the concept of smart city is constantly evolving, therefore making the scheme subject to different interpretations over time. Second, the term "quality of life", which is essential when talking about smart cities, can be interpreted differently by different parties coding it. We have tried to make the definition as clear as possible, however, in testing our coding scheme we noticed that for this theme it remains difficult. Cross-checking coded descriptions between authors, even if it is time consuming, can serve as a strategy to ensure consistent coding. Overall, with this paper, we contribute to the literature by clarifying the meaning of the concept smart city and proposing an easy-to-use way to code projects as non-smart and smart(er)-city endeavours. We trust our index will be useful for studying the role of start-ups in smart city development but can also be used beyond that field of study.

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7. Appendices

Appendix A

Author(s)	Year of publication	Times cited (total)	Times cited (per year)	Title	Journal/ Other
Albino, Berardi & Dangelico (2015)	2015	1566	261	Smart Cities: Definitions, Dimensions, Performance, and Initiatives	Journal of Urban Technology
Nam & Pardo (2011)	2011	1967	197	Conceptualizing Smart City with Dimensions of Technology, People and Institutions	12th Annual International Digital Government Research Conference
Ahvenniemi et al. (2017)	2017	484	121	What are the differences between sustainable and smart cities?	Cities
Meijer & Bolívar (2016)	2016	575	115	Governing the smart city: a review of the literature on smart urban governance	International review of administrative sciences
Cocchia (2014)	2014	621	89	Smart and digital city: A systematic literature review	Smart City
Silva, Khan & Han (2018)	2018	247	82	Towards sustainable smart cities: A review of trends, architectures, components, and open challenges in smart cities	Sustainable Cities and Society
Ismagilova et al. (2019)	2019	105	53	Smart cities: Advances in research- An information systems perspective	International Journal of Information Management
Yigitcanlar et al. (2018)	2018	111	37	Understanding 'smart cities': Intertwining development drivers with desired outcomes in a multidimensional framework	Cities
Hojer & Wangel (2014)	2014	256	37	Smart Sustainable Cities: Definition and Challenges	ICT Innovations for Sustainability
Allam & Newman (2018)	2018	93	31	Redefining the Smart City: Culture, Metabolism and Governance	Smart City
Wilhelm & Ruhlandt (2018)	2018	73	24	The governance of smart cities: a systematic literature review	Cities
Eremia, Toma, & Sanduleac (2017)	2017	86	22	The smart city concept in the 21st century	Procedia Engineering
Dameri & Rosenthal-Sabroux (2014)	2014	90	13	Smart City and Value Creation	Smart City
Cavada, Hunt, & Rogers (2014)	2014	59	8	Smart Cities: Contradicting Definitions and Unclear Measures	World Sustainability Forum
Hasija, Shen, & Teo (2020)	2020	3	3	Smart City Operations: Modeling Challenges and Opportunities	Manufacturing & Service Operations Management
Winkowska, Szpilko, & Pejić (2019)	2019	4	2	Smart city concept in the light of the literature review	Engineering Management in Production and Services
Bleus, & Crutzen (2018)	2018	1	0	Business Model and Smart City, a Literature Review	ISPIM Innovation Conference
Abdi & Shahbazitabar (2020)	2020	0	0	Smart City: A review on concepts, definitions, standards, experiments, and challenges	Journal of Energy Management and Technology
Adiyarta et al. (2020)	2020	0	0	Analysis of smart city indicators based on prisma: systematic review	IOP Conference
Samarakkody, Kulatunga & Dilum Bandara (2019)	2019	0	0	What differentiates a smart city? A comparison with a basic city	Proceedings 8th World Construction Symposium

Appendix B

Author(s)	Year of Publication	Times cited (total)	Times cited (per year)	Title	Journal/ Other	Definition of smart city	Keywords in definition
Caragliu, Del Bo, & Nijkamp (2011)	2011	3325	332.50	Smart Cities in Europe	Journal of Urban Technology	A city is smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance	Human capital, social capital, investment, modern, ICT, sustainable, economic, growth, quality of life, resource management, governance, city, transport
Townsend (2013)	2013	1617	202.13	Smart cities—big data, civic hackers and the quest for a New Utopia	Book	Smart cities are places where information technology is combined with infrastructure, architecture, everyday objects, and even our own bodies to address social, economic and environmental problems	IT, infrastructure, social wealth, place, social, economic, environmental
Neirotti et al. (2014)	2014	1381	197.29	Current trends in smart city initiatives–some stylised facts	Cities	Smart cities are characterized by a pervasive use of Information and Communication Technologies (ICT), which, in various urban domains, help cities make better use of their resources	ICT, urban, resource management
Hollands (2008)	2008	2439	187.62	Will the real smart city please stand up?	City: analysis of urban trends, culture, theory, policy, action	Smart city as (1) a celebratory label, (2) a marketing hype rather than a practical engine for infrastructural change, and (3) a loaded term carrying an uncritical, pro-development stance. For the author serious smart city projects consider human capital as the most	City, monitoring, integration, optimization, resource management, maintenance, security, citizen, services, infrastructure, energy

						important component.	
Backici et al. (2012)	2012	727	80.78	A Smart City initiative: The Case of Barcelona	Journal of the Knowledge Economy	Smart city as a high-tech intensive and advanced city that connects people, information and city elements using new technologies in order to create a sustainable, greener city, competitive and innovative commerce, and an increased life quality.	Technology, social, city, information, sustainable, green, innovation, competition, quality of life, business
Harrison et al. (2010)	2010	861	78.27	Foundations for Smarter Cities	IBM Journal of Research and Development	A city connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city	City, IT, social, infrastructure, intelligence, business
Lombardi et al. (2012)	2012	650	72.22	Modelling the Smart City Performance	Innovation: The European Journal of Social Science Research	The application of information and communications technology (ICT) with their effects on human capital/education, social and relational capital, and environmental issues is often indicated by the notion of smart city.	ICT, education, human capital, social capital, relational capital, environmental
Lee, Hancock, & Hu (2014)	2014	500	71.43	Towards an effective framework for building smart cities: Lessons from Seoul and San Francisco	Technological Forecasting and Social Change	A smart city aims to resolve various urban problems (public service unavailability or shortages, traffic, over-development, pressure on land, environmental or sanitation shortcomings and other forms of inequality) through ICT-based technology connected up as an urban infrastructure. The ultimate goal is to revitalize some of the city's structural (environmental	Solutions, environmental, inequality, ICT, infrastructure, efficiency, sustainable, city, quality of life, livability, economic, social, information

						and social) imbalances through the efficient redirection of information. Smart cities are envisioned as creating a better, more sustainable city, in which people's quality of life is higher, their environment more liveable and their economic prospects stronger.	
Washburn & Sindhu (2010)	2010	683	62.09	Helping CIOs Understand "smart City" Initiatives: Defining the Smart City, Its Drivers, and the Role of the CIO	Cambridge, MA: Forrester Research, Inc.	The use of smart computing technologies to make the critical infrastructure components and services of a city- which include city administration, education, healthcare, public safety, real estate, transportation, and utilities - more intelligent, interconnected and efficient	Technology, infrastructure, services (administration, education, healthcare, public safety, real estate, transportation, utilities), intelligence, interconnected, efficiency
Gretzel et al. (2015, p. 559)	2015	343	57.17	Conceptual foundations for understanding smart tourism ecosystems	Computers in Human Behavior	A smart city is a city that uses advanced ICT to optimize resource production and consumption	ICT, resource management
Zygiaris (2013)	2013	451	56.38	Smart City Reference Model: Assisting Planners to Conceptualize the Building of Smart City Innovation Ecosystems	Journal of the Knowledge Economy	The term "smart city" is understood as a certain intellectual ability that addresses several innovative socio-technical and socio-economic aspects of growth. These aspects lead to smart city conceptions as "green" referring to urban infrastructure for environment protection and reduction of CO2 emission, "interconnected" related to revolution of broadband economy, "intelligent" declaring the	Intelligence, innovation, technology, economic, growth, green, infrastructure, environment, interconnected, intelligence, information, data, sensors, activators, knowledge, creative, human capital, city

						capacity to produce added value information from the processing of city's real-time data from sensors and activators, whereas the terms "innovating", "knowledge" cities interchangeably refer to the city's ability to raise innovation based on knowledgeable and creative human capital	
Lazaroiu & Roscia (2012)	2012	462	51.33	Definition Methodology for the Smart Cities Model	Energy	A community of average technology size, interconnected and sustainable, comfortable, attractive and secure.	Community, technology, sustainable, interconnected, comfortable, attractive, secur ity
Antopoul os et al. (2019)	2019	101	50.50	A Unified Smart City Model (USCM) for smart city conceptualiz ation and benchmarkin g	Smart Cities and Smart Spaces: Concepts, Methodologies , Tools, and Applications	All means of innovations in the urban atmosphere (ICT-based, yet not necessarily) that purpose to improve the city dimensions including economy, people, government, mobility, environment and living	Innovation, urban, ICT, economy, people, government, mobility, environment, quality of life
Dameri (2013)	2013	360	45.00	Searching for smart city definition: A comprehensi ve proposal	International Journal of Computer Technology	A Smart City is a well-defined geographical area, in which high technologies such as ICT, logistic, energy production, and so on, cooperate to create benefits for citizens in terms of well-being, inclusion and participation, environmental quality, intelligent development; it is governed by a well-defined pool of subjects, able to state the rules and policy for the city government and development"	Geographical area, technology, energy, well-being, citizen, inclusion, participation, environmental, intelligence, development, rules, policy, governance, ICT, logistics
Marsal-Llacuna et al. (2015)	2015	258	43.00	Lessons in urban monitoring taken from sustainable and livable	Technological Forecasting and Social Change	Smart Cities initiatives try to improve urban performance by using data, information and	Urban, data, services, citizens, efficient, innovation, IT, monitoring,

				cities to better address the Smart City initiative		information technologies (IT) to provide more efficient services to citizens, to monitor and optimize existing infrastructure, to increase collaboration among different economic actors, and to encourage innovative business models in both the private and public sectors.	optimization, infrastructure, collaboration, economic, governance, performance, information
Piro et al. (2014, p. 169)	2014	291	41.57	Information centric services in smart cities	Journal of Systems and Software	A smart city is intended as an urban environment which, supported by pervasive ICT systems, is able to offer advanced and innovative services to citizens in order to improve the overall quality of their life.	ICT, innovation, social, quality of life, urban, citizens, services
Hernandez-Munoz et al. (2011)	2011	409	40.90	Smart cities at the forefront of the future internet	The future internet assembly	A city that represents an extraordinary rich ecosystem to promote the generation of massive deployments of city-scale applications and services for a large number of activity sectors	City, ecosystem, services
Khatoun & Zeadally (2016, p. 46)	2016	202	40.40	Smart cities: Concepts, architectures, research opportunities	Communications of the ACM	A smart city is an ultra-modern urban area that addresses the needs of businesses, institutions and especially citizens	Urban, business, institutions, citizens, modern
van Zoonen (2016, p. 472)	2016	164	32.80	Privacy concerns in smart cities	Government Information Quarterly	In a smart city, ICT-infused infrastructures enable the extensive monitoring and steering of city maintenance, mobility, air and water quality, energy usage, visitor movements, neighbourhood sentiment, and so on.	ICT, monitoring, resource management, transportation, city, mobility, energy, maintenance, community

Winters (2011)	2011	310	31.00	Why are smart cities growing? Who moves and who stays	Journal of Regional Science	I consider "smart cities" to be metropolitan areas with a large share of the adult population with a college degree	Urban, citizens, high education
Gil-Garcia, Zhang, & Puron-Cid (2016)	2016	153	30.60	Conceptualizing smartness in government: An integrative and multi-dimensional view	Government Information Quarterly	A city is smart when there are actions taken towards innovation in management, technology, and policy, all of which entail risks and opportunities	Innovation, management, technology, policy, opportunities, risks, city
Toppeta (2010)	2010	318	28.91	How innovation and ict can build smart, "livable", sustainable cities	Innovation Knowledge Foundation	A city "combining ICT and Web 2.0 technology with other organizational, design and planning efforts to dematerialize and speed up bureaucratic processes and help to identify new, innovative solutions to city management complexity, in order to improve sustainability and livability	ICT, technology, design, planning, governance, innovation, solutions, sustainability, livability, efficiency, management, city, organization
Schuurman et al. (2012, p. 51)	2012	243	27.00	Smart ideas for smart cities: Investigating crowdsourcing for generating and selecting ideas for ICT innovation in a city context	Journal of Theoretical and Applied Electronic Commerce Research	In smart cities collaborative digital environments facilitate the development of innovative applications, starting form the human capital of the city, rather than believing that the digitalization *in se* can transform can improve cities.	Innovation, improvement, development, collaboration, human capital, city, digital
Kourtit et al. (2012)	2012	240	26.67	Smart Cities in Perspective - a Comparative European Study by Means of Self-organizing Maps	Innovation: The European Journal of Social Science Research	Smart cities have high productivity as they have a relatively high share of highly educated people, knowledge-intensive jobs, output-oriented planning systems, creative activities and sustainability-oriented initiatives.	Productivity, education, (skilled) job, creativity, sustainability, planning, systems, activities
Huovila et al. (2019)	2019	51	25.50	Comparative analysis of standardized indicators for	Cities	An innovative city that uses information and communication	Innovation, city, ICT, quality of life, efficiency, services,

				Smart sustainable cities: What indicators and standards to use and when?		technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects	competition, economic, social, environmental, cultural, sustainable
Hall et al. (2000)	2000	533	25.38	The vision of a smart city	2nd International Life Extension Technology Workshop (Paris)	An urban centre of the future, made safe, secure environmentally green, and efficient because all structures– whether for power, water, transportation, etc. are designed, constructed, and maintained making use of advanced, integrated materials, sensors, electronics, and networks which are interfaced with computerized systems comprised of databases, tracking, and decision-making algorithms	Urban, green, efficiency, integration, interface, ICT, algorithms, safety, security, transportation, energy, water, design, sensors, networks, technology, database
Lee & Lee (2014, p. 93)	2014	175	25.00	Developing and Validating a citizen-centric typology for smart city services	Government Information Quarterly	A city which develops and manages a variety of innovative services that provide information to all citizens about all aspects of city life via interactive and internet-based applications	City, innovation, information, services, ICT, technology, citizens, internet, livability
Belissent (2010)	2010	266	24.18	Getting clever about smart cities: New opportunities require new business models	Cambridge: Forrester	A city that uses ICTs to make the critical infrastructure components and services of a city– administration, education, healthcare, public safety, real estate, transportation,	ICT, infrastructure, services (administration, education, healthcare, public safety, real estate, transportation, utilities), interaction, efficiency

						and utilities–more aware, interactive, and efficient	
Pereira et al. (2017, p. 528)	2017	88	22.00	Delivering public value through open government data initiatives in a smart city context.	Information Systems Frontiers	A smart city encompass an efficient, technologically advanced, sustainable and socially inclusive city	Efficient, technology, sustainable, social, inclusion, city
Zhuhadar et al. (2017, p. 274)	2017	86	21.50	The next wave of innovation-Review of smart cities intelligent operation systems.	Computers in Human Behavior	Those cities that have the greatest quality of life and economic wellbeing for their citizens	Quality of life, economic, well-being, citizens, city
Paskalev a (2009)	2009	257	21.42	Enabling the smart city: The progress of city e-governance in Europe	International Journal of Innovation and Regional Development	A city that takes advantages of the opportunities offered by ICT in increasing local prosperity and competitiveness–an approach that implies integrated urban development involving multi-actor, multi-sector and multi-level perspectives	ICT, development, competition, opportunities, collaboration, city, prosperity
Komninos (2011)	2011	214	21.40	Intelligent Cities: Variable Geometries of Spatial Intelligence	Intelligent Buildings International	(Smart) cities as territories with high capacity for learning and innovation, which is built-in the creativity of their population, their institutions of knowledge creation, and their digital infrastructure for communication and knowledge management.	Territories, learning, innovation, creativity, knowledge, digital, citizens, ICT
Kourtit & Nijkamp (2012)	2012	187	20.78	Smart Cities in the Innovation Age	Innovation: The European Journal of Social Science Research	Smart cities are the result of knowledge-intensive and creative strategies aiming at enhancing the socio-economic, ecological, logistic and competitive performance of cities. Such smart cities are based on a promising mix of human capital (e.g. skilled labor force), infrastructural	City, economic, ecological, logistic and competitive performance, human capital, social capital, entrepreneurship, creativity, knowledge, infrastructure, business

						capital (e.g. high-tech communication facilities), social capital (e.g. intense and open network linkages) and entrepreneurial capital (e.g. creative and risk-taking business activities).	
Odendaal (2003)	2003	366	20.33	Information and communication technology and local governance: understanding the difference between cities in developed and emerging economies	Computers, Environment and Urban Systems	A city that capitalises on the opportunities presented by ICTs in promoting its prosperity and influence.	City, opportunities, ICT, capitalization, prosperity
Xie et al. (2019)	2019	37	18.50	A Survey of Blockchain Technology Applies to Smart Cities: Research Issues and Challenges	IEEE Communications Surveys and Tutorials	Upgraded quality of life, sustainable urban environment, use of advanced ICT, public government openness, encouraged community participation, effective management of traffic and public transport, intelligent device control, optimum resource utilization, improved environmental protection, and improved public services	Quality of life, sustainable, urban, ICT, governance, community, participation, efficiency, transport, resource management, environmental, public services
Lara et al. (2016)	2016	92	18.40	Smartness that matters: Towards a comprehensive and human-centred characterisation of smart cities	Journal of Open Innovation: Technology, Market, and Complexity	A community that systematically promotes the overall wellbeing for all of its members, and flexible enough to proactively and sustainably become an increasingly better place to live, work and play	Community, well-being, livability, sustainability, proactive, citizens, flexibility, quality of life
Yeh (2017, p. 556)	2017	72	18.00	The effects of successful ICT-based smart city	Government Information Quarterly	A general definition involves the implementation	ICT, social, growth, urban, economy, efficiency,

				services: From citizens' perspectives		and deployment of information and communication technology (ICT) infrastructures to support social and urban growth through improving the economy, citizens' involvement and government efficiency	citizen (involvement), government
Hussain et al. (2015, p. 253)	2015	107	17.83	Health and emergency-care platform for the elderly and disabled people in the smart city	Journal of Systems and Software	The smart cities are using digital technologies to enhance the quality and performance of urban services	Digital, technology, quality, performance, urban, services
Ygitcanlar (2015)	2015	100	16.67	Smart cities: an effective urban development and managemen t model?	Australian Planner	A city in which the traditional services and networks based on digital technologies are made more efficient for the benefit of its businesses, services, and inhabitants	City, technology, digital, efficiency, businesses, services, networks, inhabitants
Gascó-Hernandez (2018, p. 50)	2018	45	15.00	Building a smart city: lessons from Barcelona	Communications of the ACM	A smart city is an umbrella term of how information and communication technology can help improve the efficiency of a city's operations and its citizens' quality of life while also promoting the local economy	ICT, efficiency, improvement of operations, quality of life, citizens, city
Barrionuevo, Berrone, & Ricart (2012)	2012	134	14.89	Smart Cities, Sustainable Progress	IESE Insight	Being a smart city means using all available technology and resources in an intelligent and coordinated manner to develop urban centers that are at once integrated, habitable, and sustainable.	Technology, resource management, intelligence, coordination, urban, integration, sustainable, habitable
Ygitcanlar (2016)	2016	73	14.60	Technology and the city: Systems, applications and implications	New York: Routledge	An ideal form to build the sustainable cities of the 21st century, in the case that a balanced and sustainable view on economic,	City, sustainable, economic, societal, environmental, institutional, development

						societal, environmental and institutional development is realised.	
Mahizhnan (1999)	1999	313	14.23	Smart cities: The Singapore case	Cities	Information technologies represent the key concept. The vision of an intelligent city is not confined to economic excellence that can be led by information technologies, but an integral part of this vision is its concern for the quality of life for the ordinary citizen.	IT, quality of life, economic, citizen, city
Chatterjee, Kar, & Gupta (2018)	2018	38	12.67	Success of IoT in Smart Cities of 2018 Journal India: An empirical analysis	Government Information Quarterly	Smart Cities where the citizens are expected to use Information and Communication Technology with the help of internet.	ICT, citizen, internet
Rana et al. (2018, p. 1)	2018	37	12.33	Barriers to the development of smart cities in Indian context	Information Systems Frontiers	Smart cities can be defined as a technologically advanced and modernised territory with a certain intellectual ability that deals with various social, technical, economic aspects of growth based on smart computing techniques to develop superior infrastructure constituents and services	Technological, intelligence, social, technical, economic, infrastructure, modern, services, growth, territory
Komninos et al. (2015)	2015	72	12.00	Smart city ontologies: Improving the effectiveness of smart city applications	URENIO Research	Smart cities are created by a convergence of top-down and bottom-up processes, wherein market forces and strategic planning come together to build broadband networks, urban operational systems, embedded systems, and software, all of which change the functioning and life in cities.	Top-down, bottom-up, planning, network, operational, systems, software, quality of life, city

Giffinger et al. (2007)	2007	148	10.57	Smart cities: ranking of European medium-sized cities	Vienna: Centre of Regional Science - Vienna UT	A city well 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	Economy, people, governance, mobility, environment, livability, aware ness, citizens, activities, self-decisive, city
Thite (2011)	2011	105	10.50	Smart Cities: Implications of Urban Planning for Human Resource Developmen t	Human Resource Development International	Creative or smart city experiments [. . .] aimed at nurturing a creative economy through investment in quality of life which in turn attracts knowledge workers to live and work in smart cities. The nexus of competitive advantage has [. . .] shifted to those regions that can generate, retain, and attract the best talent.	Creativity, economic, quality of life, livability, competitive advantage, talent acquirement, knowledge
Cretu (2012)	2012	84	9.33	Smart Cities Design Using Event-driven Paradigm and Semantic Web	Informatica Economica	A smart city has well designed ICT infrastructure, transforms real time data into meaningful information, a smart city allows inhabitants to predefine automated actions in response to events	ICT, data, information, inhabitants, automation, events
Eger (2009)	2009	110	9.17	Smart growth, smart cities, and the crisis at the pump a worldwide phenomenon	The Journal of E-Government Policy and Regulation	A particular idea of local community, one where city governments, enterprises and residents use ICTs to reinvent and reinforce the community's role in the new service economy, create jobs locally and improve the quality of community life	Community, governance, technology, livability, productivity, ICT, quality of life, city, businesses, inhabitant, economy
Bartoli et al. (2011)	2011	85	8.50	Security and privacy in your smart city	Proceedings of the Barcelona smart cities congress	The main topics are SCs are related to of their smart inhabitants,	Inhabitants, social, education,

						quality of social interaction, educational degree, integration with public life, as well as openness to the wider world.	integration, openness
Peng, Nunes & Zheng (2017)	2017	32	8.00	Impacts of low citizen awareness and usage in smart city services: the case of London's smart parking system	Information Systems and e-Business Management	Smart cities are essentially built by utilising a set of advanced information and communication technologies (ICT), including smart hardware devices (e.g. wireless sensors, smart meters, smart vehicles, and smartphones), mobile networks (e.g. WIF, 3G/4G/5G network), data storage technologies (e.g. data warehouse, cloud platform), and software applications (e.g. back-office control systems, mobile apps, big data analytical tools)	ICT, data, network, technology, software, hardware, devices
Chen (2010)	2010	88	8.00	Smart Grids, Smart Cities Need Better Networks	IEEE Network	Smart cities will take advantage of communications and sensor capabilities sewn into the cities' infrastructures to optimize electrical, transportation, and other logistical operations supporting daily life, thereby improving the quality of life for everyone	Communications , sensors, infrastructure, optimization, electricity, transportation, logistics, quality of life
Corbett and Mellouli (2017, p. 428)	2017	31	7.75	Winning the SDG battle in cities: How an integrated information ecosystem can contribute to the achievement of the 2030 sustainable development goals	Information Systems Journal	Smart cities seek to leverage advanced communication technologies and IS (information systems) in order to improve all areas of city administration, enhance citizens' quality of life, engage citizens and provide more sustainable and	ICT, city, administration, quality of life, citizen (engagement), sustainable, services

						resilient public services	
Thuzar (2011)	2011	77	7.70	Urbanization in SouthEast Asia: developing smart cities for the future?	Regional Outlook	Smart cities of the future will need sustainable urban development policies where all residents, including the poor, can live well and the attraction of the towns and cities is preserved. […] Smart cities are […] cities that have a high quality of life; those that pursue sustainable economic development through investments in human and social capital, and traditional and modern communications infrastructure (transport and information communication technology); and manage natural resources through participatory policies. Smart cities should also be sustainable, converging economic, social, and environmental goals	Development, city, quality of life, policy, inhabitants, human capital, social capital, ICT, resource management, sustainable, economic, environmental, infrastructure, transport, modern
Schiavonea, Paolonec, & Mancinia (2019)	2019	15	7.50	Business model innovation for 2019 urban smartization	Technological Forecasting & Social Change	Smart cities are the result of a combination of investments made in resources (human, social, creative, infrastructural, technological and business capital) that encourage sustainable economic growth under the conditions of a strong management and governance system (Caragliu et al., 2011)	Investments, resources, sustainable, economic, growth, governance, human capital, social capital, creativity, infrastructure, business capital, technology
Schaffers et al. (2012, p. 2)	2012	66	7.33	Special issue on smart applications for smart cities - new	Journal of Theoretical and Applied Electronic	The smart city is an urban innovation ecosystem, a living laboratory	Urban, innovation, ecosystem, laboratory

				approaches to innovation: Guest editors' introduction	Commerce Research	acting as agent of change	
Zhao (2011)	2011	70	7.00	Towards sustainable cities in China: Analysis and assessment of some Chinese cities in 2008	Berlin: Springer	A city that improves the quality of life, including ecological, cultural, political, institutional, social, and economic components without leaving a burden on future generations.	City, quality of life, ecological, cultural, political, institutional, social, economic, sustainable
Heaton & Parkilad (2019)	2019	14	7.00	A conceptual framework for the alignment of infrastructure assets to citizen requirements within a Smart Cities Framework	Cities	The concept of Smart City engages with cities' stakeholders and encompasses all of the built and natural environment	City, stakeholders, environment
Rios (2012)	2012	62	6.89	Creating the smart city	Thesis	A city that gives inspiration, shares culture, knowledge, and life, a city that motivates its inhabitants to create and flourish in their own lives—it is an admired city, a vessel to intelligence, but ultimately an incubator of empowered spaces	City, culture, knowledge, life, intelligence, inhabitants, incubator
El-Haddadeh et al. (2018, p. 1)	2018	20	6.67	Examining citizens' perceived value of internet of things technologies in facilitating public sector services engagement	Government Information Quarterly	Smart cities are all about networks of sensors, smart devices, real-time data, and ICT integration in every aspect of human life	Network (of sensors, smart devices, real-time data), ICT, citizen
Qian et al. (2019)	2019	13	6.50	The Internet of Things for Smart Cities: Technologies and Applications (Guest editorial)	IEEE Network	Human and societal capital investments, modern-day communication, infrastructure, sustainable economic growth, participatory governance, natural resources management, and advanced	ICT, communication, sustainable, economic, growth, governance, resource management, human capital, social capital, investment, physical infrastructure,

						infrastructure (physical, modern ICT, social, and business) integration to sustain the city's collective intelligence	business, integration, intelligence
Outlook (2014)	2014	43	6.14	Early Release Overview	US Energy Information Administration	A city that uses ICT to be more interactive, efficient, and making citizens more aware of what is happening in the city.	City, ICT, interaction, efficiency, awareness, citizens
Calderoni, Maio, & Palmieri (2012, p. 74)	2012	55	6.11	Location-aware mobile services for a smart city: Design, implementation, and deployment	Journal of Theoretical and Applied Electronic Commerce Research	A smart city is high-performance urban context, where citizens are more aware of, and more integrated into the city life, thanks to an intelligent city information system	Performance, urban, citizen, awareness, integration, IT
Partridge (2004)	2004	96	5.65	Developing a human perspective to the digital divide in the smart city	ALIA 2004 Biennial Conference: Challenging ideas, Gold Coast, Australia	A city that actively embraces new technologies seeking to be a more open society where technology makes easier for people to have their say, gain access to services and to stay in touch with what is happening around them, simply and cheaply	City, technology, quality of life, services, openness
Alkandari, Alnasheet, & Alshaikhli (2012)	2012	48	5.33	Smart cities: a survey	Journal of Advanced Computer science and Technology Research	A city that uses a smart system characterised by the interaction between infrastructure, capital, behaviours and cultures, achieved through their integration	Systems, interaction, integration, infrastructure, capital, behaviour, city, culture
Heo et al. (2014)	2014	35	5.00	Escaping from ancient Rome! Applications and challenges for designing smart cities	Transactions on Emerging Telecommunications Technologies	An urban environment which able to improve the quality of citizens' life by using ICT systems	Urban, quality of life, citizens, ICT
Chong et al. (2018, p. 10)	2018	14	4.67	Dynamic capabilities of a smart city: An innovative approach to discovering urban problems	Government Information Quaterly	Smart city is an integration of infastructures and technology-mediated services, social learning for strengthening human	Integration, infrastructure, technology, services, social learning, human, governance, instiutional, improvement,

				and solutions		infrastructure, and governance for institutional improvement and citizen engagement	citizen (engagement)
Guan (2012)	2012	41	4.56	Smart Steps To A Battery City	Government News	A city that is prepared to provide conditions for a healthy and happy community under the challenging conditions that global, environmental, economic and social trends may bring.	City, community, challenges, environment, economic, social, quality of life, global
Shafiullah et al. (2010)	2010	44	4.00	Potential challenges: integrating renewable energy with the smart grid	20th Australasian Universities Power Engineering Conference	Smart cities are characterized by the pervasive use of ICT to smartness application in natural resources and energy, transportation and mobility, buildings, living, government, economy, and people.	ICT, energy, transportation, mobility, buildings, living, government, economy, people, resource management
Chang et al. (september, 2019)	2019	5	2.50	Multivariate relationships between campus design parameters and energy performance using reinforcement learning and parametric modeling	Applied Energy	The main features of the smart city are smart economy, smart mobility, smart environment, smart people, smart living, and smart governance.	Economy, mobility, environment, people, living, governance
European Parliament (2014)	2014	17	2.43	Mapping smart cities in the EU	Economic and scientific policy	A city seeking to address public issues via ICT-based solutions on the basis of a multi-stakeholder, municipally based partnership	City, ICT, solutions, issues, partnerships, municipality
David & Koch (2019)	2019	3	1.50	"Smart Is Not Smart Enough!" Anticipating Critical Raw Material Use in Smart City Concepts: The Example of Smart Grids	Urban Transformations Towards Sustainability	A city that tries to make resource production and allocation in urban areas more efficient, and thus more sustainable through new sociotechnical innovations such as smart grids, smart meters, or solar panels.	City, resource management, efficiency, sustainable, innovation, technology (solar panels, smart meters, smart grids), urban

Appendix C1

#	Themes	% of appearances in total number of definitions
1.	Technology (data, sensors, activators, internet, ICT, IT, database, algorithm, grid, digital, solar panels, smart meters, WIFI, software, hardware, smart devices)	80.9%
2.	City/ urban challenges (territory, place, geographical area)	75.6%
3.	Sustainability (green, environmental, ecological)	50.2%
4.	ICT (if 1, also add 1 to technology)	49.6%
5.	Social capital (social, social wealth, inclusion, community)	48.4%
6.	Economic (economy)	38.6%
7.	Quality of life (liveability, prosperity, habitable, well-being)	38.1%
8.	Human capital (intelligence, skilled workers/ jobs, (high) education, knowledge)	35.4%
9.	Resource management	34.8%
10.	Infrastructure	32.2%
11.	Citizen (inhabitants, people)	29.2%
12.	Transportation (mobility, transport)	23.4%
13.	Innovation	17.8%
14.	Growth	17.5%
15.	Efficiency (efficient)	14.3%
16.	Safety (security)	14.1%
17.	Energy	10.9%
18.	Business (entrepreneurship)	10.5%
19.	Integration	10.5%
20..	Collaboration (participation, partnership, relational capital, coordination, stakeholder)	9.5%
21.	Network (interconnected)	8.6%
22.	Creativity	5.8%

Appendix C2

#	Themes	% of appearances in total number of citations (per year)
1.	Technology (data, sensors, activators, internet, ICT, IT, database, algorithm, grid, digital, solar panels, smart meters, WIFI, software, hardware, smart devices)	74.0%
2.	City/ urban challenges (territory, place, geographical area)	72.6%
3.	ICT (if 1, also add 1 to technology)	43.8%
4.	Citizen (inhabitants, people)	42.5%
5.	Sustainability (green, environmental, ecological)	39.7%
6.	Quality of life (liveability, prosperity, habitable, well-being)	39.7%
7.	Social capital (social, social wealth, inclusion, community)	34.2%

8.	Economic (economy)	31.5%
9.	Human capital (intelligence, skilled workers/ jobs, (high) education, knowledge)	28.8%
10.	Infrastructure	21.9%
11.	Efficiency (efficient)	17.8%
12.	Innovation	17.8%
13.	Transportation (mobility, transport)	16.4%
14.	Resource management	15.1%
15.	Business (entrepreneurship)	11.0%
16.	Collaboration (participation, partnership, relational capital, coordination, stakeholder)	11.0%
17.	Network (interconnected)	9.6%
18.	Integration	11.0%
19.	Growth	8.2%
20..	Creativity	8.2%
21.	Safety (security)	6.8%
22.	Energy	5.5%