Evolutionary Trends in Smart City Initiatives

No 3 (2021) 100052

Contents lists available at ScienceDirect

Sustainable Futures

journal homepage: www.sciencedirect.com/journal/sustainable-futures

Evolutionary trends in smart city initiatives

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ARTICLE INFO

Keywords:
Smart city
Urban policy
Empirical analysis
Smart mobility
Smart energy
Smart buildings

ABSTRACT

Smart Cities (SC) have claimed to improve the quality of life of citizens, but the notion of SC is variegated and it has been changing its form. As a contribution to understand the evolutionary trends of Smart Cities, this paper analyzes the characteristics of SC programs, and the role of a set of contextual variables of SC projects adoption has been investigated. The results reveal that big innovative cities are less willing to develop SC projects, that in the building domain are driven by innovative trends and projects in the energy sector depend on the level of wealth.

1. Introduction

Recent urbanization trends have been driving most of the challenges that have in turn created the need for Smart City (SC) initiatives [1]. In fact, it is expected that by 2050 66% of the global population will be living in urban areas. This dramatically rapid growth might negatively impact on a sustainable development [2] with consequent significant problems of social inclusion, air pollution, waste management, and energy consuption [3]. In particular, cities, altough extending to only 3% of the earth's land area, are now consuming about 75% of global resources and contributing for 80% of greenhouse emissions, which result in heavy impacts on environmental conditions both locally and globally [4]. Thus, cities play a prime role in social, economic and environmental aspects all over the world and SCs have emerged as a leading approach for addressing these issues [5].

The concept of SC has come up in the late 1990s based on the idea that there should be an integration among the systems related to the services that assist living in urban areas, connecting human and technological capital and seeking ways to improve the relations between the city and its population [6]. The notion of SC has become more and more popular in the academic literature [7] and the international contributions in this field are increasing in number [8]. Scholars have proposed different definitions of SC, but all agree that a SC includes technologies and knowledge aimed at connecting people, develop intelligent buildings and enhancing transport systems [9].

However, there is still no consensus about what really makes a city smarter and the notion of SC is not yet shared [6]. Also, SCs are going to face new challenges such as the acceptance of latest techological paradigms in order to take into account local cultural differences and adaptation of information technologies to the local area wherein smart programs are developed [10]. Furthermore, a multitude of definitions of SC are available, but none is universally acknowledged [11].The increasing diffusion of models, standards and definitions of SC is creating ambiguity and makes it difficult to estimate whether SCs are aligned with the original expectations and the ideals claimed by their promoters [12] . In fact, during the first development phases expectations of SC benefits were high. In particular, SCs were considered as levers to create advantages for citizens in terms of well being, social inclusion, quality of environment and intelligent development [13]. However, several recent studies have been raising concerns about ongoing SC initiatives [14]: SC programs have been criticized for being too tech-centric, mainly driven by big Information and Communication Technologies (ICT) companies which own the SC agendas and in turn of lacking of enough attention to citizens' needs and real environmental sustainability [15]. Thus, the critical issue is associated with the generation of the value expected by the citizenship and more in general by the involved stakeholders.

Moreover, academic studies still keep on focusing discussions about definitions and domains related to the SC notion without taking into account for its evolution pathways that is becoming more and more crucial [16]. In particular, few studies are available to analyze how the SC notion has changed over time and to questioning whether the current SC trends are far or different from the original expectations.

In order to contribute to bridging these research gaps, this paper aims at (i) identifying current SC trends and (ii) comparing the current state of diffusion of SC initiatives with the initial original expectations in

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https://doi.org/10.1016/j.sftr.2021.100052
Received 10 February 2021; Received in revised form 23 April 2021; Accepted 5 May 2021
Available online 20 May 2021

various fields of application in order to verify whether SC are effective levers for generating value in terms of quality of life for citizens and environmental sustainability.

To this end, a dataset of 83 cities that claim to have developed SC projects in the last years is collected worldwide and analysed using their Coverage Index (CI), which considers the number of projects that have been carry out in the identified SC application domains (Neirotti et al., 2014). The CI is a measure to assess the extent of the smartness of a city in relation to the application domains. The dataset considers SC projects developed from 2014 to 2018 in order to focus the attention on the most recent application of SC initiatives. Then, to understand the SC current trends and detect possible evolution paths over the last five years, the sample is compared with previous studies, which collected similar data from 2009 to 2013 [17]. In particular, the empirical analysis is aimed at identifing the SC domains with largest diffusion of SC initiatives internationally, to underline commonalities and differences in the evolution patterns accross continents and how some main contextual variables may have affected the SC development. Thus the goal of the paper is to update is to analyze how the SC notion has changed over the last years and wheather SCs have confirmed or failed their original promises.

The paper is structured as follows. First, a literature overview about the notion of SC is proposed. The literature is then focused on the analysis of the application domains for a SC and on the identification of the main contextual variables that are likely to influence the willingness in developing SC initiatives. Second, the methodology and the data gathered are presented. Then, the relationships between the CI and several contextual variables are examined using a correlation analysis, and results are discussed together with their theoretical and practical implications. Finally, limitations and possible future research directions are addressed.

2. Literature review

Since its outset, the SC has been perceived as an effective concept for transforming urban areas, enhancing the quality of life and improving environmental sustainability [18]. In other terms, SCs have been conceived as a mean to face the problems deriving from increasing urbanization [19]. The number of people moving to live in urban contexts is steadily growing with significant impact on pollution, employment, energy demand, waste and public budgets. [20]. A SC can be considered as a change in urban planning, engineering and design that involves multiple disciplines, diverse technologies and many domains of applications for promoting inclusive and sustainable economic growth. It includes different city concepts such as information city, sustainable city, talented city, wired city, digital city and eco city [21]. From a general point of view, a SC is an urban environment that exploits ICTs and related enabling technologies, as a mean to enhance the efficiency of cities in terms of urban operations and quality of services provided to the citizens while ensuring that the needs of future generations are met considering economic, social, sustainable and cultural aspects. [22]. Four are the pillars that support the development of projects in the SC arena, namely: institutional, physical, social and economic pillars [23]. Thanks to these broad ranges of applications, a lot of SC projects have been carried out all around the world [24] in order to provide efficient services to citizenship. These goals are reached through the combination of the adoption of ICT systems, the implementation of new governance models and the focus on human capital [7]. In particular, ICT systems include Internet of Things (IoT) and big data: by exploiting sensors, these technologies are able to monitor and optimize power consuption clouds [25]. In this sense, IoT can be viewed as a lever to gather and provide data to end users and policy makers for enhancing the overall ecosystem of a SC [26] with minimal human intervention. Thus, in recent years IoT is paving the way for facilitating the development of SCs [27].

Nevertheless, a SC can be also considered at a local scale because each city is unique, it deals with different problems and it should provide for different solutions. In this sense, each city implements its own SC strategy by taking into account its local aspects such as the geographical, territorial and cultural backgrounds [19]. Furthermore, it can be assumed that SC projects are easier to implement in developed countries as they are equipped with more advanced technologies, stronger financial resources and more mature city planning strategies . On the contrary, developing countries have their financial commitments to achieve basic services and it becomes difficult to pursue SC initiatives [28].

However, the SC notion is still not well defined and not fully understood: a standardized and shared definition is missing and a lack of general consensus can be observed in the scholarly literature [29] Based on different definitions, a SC can take a specific focus such as digital infrastructure, ICT usage, business-led development, creative industries, social capital or environmental sustainability [30] that might be pursued through investments in sustainable public transport, increase of green spaces and envinronemtal public policies [31]. Despite increased popularity of the SC notion and its large presence in the literature, there are still few rigorous analytical or statistical analyses about the definition of a SC, its application domains, the way the SC notion is declined in different regions worldwide and its evolution trends [32]. As part of this limited kind of statistical works, [17] provided for a comprehensive global study that explains how a SC is declined with a focus on either hard domains or soft domains at different geographical locations and how its evolution is affected by local context factors. Similarly, [33] propose an empirical analysis to understand the main drivers that originate the launch of SC initiatives worldwide, which include improving the quality of life of citizens, generating positive externalities for the economy and making cost savings on the municipal budget. In this context, [34] identified two main evolution pathways for SC programs. The first one is related to human and social capital, governance, and environment, while the second stream of application is based on the development of technology.

More recently, a stream of research is underling the negative issues and how SCs have failed to meet their initial purposes [6,35]. In particular, SCs are claimed to have been mainly focusing on ICTs without placing sufficient emphasis on the cities' needs in terms of environmental friendliness and quality of life [37]. Also, the global diffusion is not mainstreamed because of technological, economical and governing barriers [22].

2.1. Application domains of SC

The most important aspects that a SC should address are a networked infrastructure enabling political efficiency and social development, together with the implementation of activities that might support the promotion of a sustainable urban growth [7]. In particular, [38] identify the technology, the people and the institutions as the main application domains of a SC. According to [39] there are six domains that could be referred to the different aspects of urban life, namely: economy, people, governance, mobility, environment, and living. Similarly, [17] classify the SC definition into six application domains, namely:

- Natural Resources & Energy, reffering to wise management of the natural resources and an effective use of the energy [40];
- Transport & Mobility: initiatives in this fields foster the development of integrated systems wherein all the stakeholders are coordinated so that to reduce the negative impacts – such as pollution, and traffic congestion – on citizens [41]
- Buildings: by monitoring its main elements such as air conditioners, lights, windows, doors, it is possible to configure the environment according to the human needs and to efficiently manage the energy consuption [42].
- Living: this dimension depicts the local quality of life [43].

- Governments: it can have an important role in achieving positive results in SCs by innovating both the internal organization and the policies issued [44]
- Economy, and People: this domain includes all the measures that foster innovation in urban systems and they result in increasing the availability for the citizens also in terms of cost [17]. It is important to provide good options for leisure and fun, cultural initiatives and education [37].

Each category is then subdivided into several sub-domains as given in Table 1, which also reports the relevant corresponding literature.

3. Research methodology

This research is an empirical analysis and is developed as follows.

First, a worldwide dataset is collected from 83 cities that have been implementing SC programs in one or more domains or subdomains as identified in Table 1. The cities' list is provided in the Appendix. The dataset period ranges from 2014 to 2018 in order to focus on recent trends of the SC evolution and to make it comparable with a same five-years length dataset reported by [17] who have studied the period from 2009 to 2013. A value equal to 1 or 0 is given for each sub-domain to reflect whether a city reports a SC project carried out in that specific sub-domain or not. For example, if a digital platform to manage the booking of loading and unloading areas in the city center is available, a 1 score value is assigned for the City Logistics sub-domain. Then, the Coverage Index (CI) is calculated as defined by [17]. The CI is the weighted summation of the 0/1 scores assigned to all identified sub-domains. Its goal is to assess the number of subdomains covered by the SC action and the extent to which a city embraces multiple SC domains. In this sense, it can be regarded as a proxy for assessing the level of smartness of a city. Also, an aggregated CI is calculated as the sum of the six indices obtained at the domain level. This index represents the number of domains covered by SC project for each city of the sample and used for addressing the way a city is involved in the different smart dimensions [66].

Second, some contextual variables are collected to characterize the context in which SC projects have been developing. These refer to structural, technological, economic, and environmental variables that are expected to influence the CI. The list of the contextual variables and their explaination is given in the following Section.

Then, both the CI and contextual variables are analyzed to understand connections, current trends and directions. In particular, descriptive statistics are used to identify the SC domains with largest diffusion of SC initiaves throughout the world, the analysis of variance is carried out at both the domain and sub-domain levels to underline commonalities and differences in the evolution patterns across continents over time, and a correlation analysis is then applied in order to evaluate how the collected contextual variables might affect the different domains and subdomains of the CI.

Finally, results are compared with those obtained by [17] to better capture the changes in evolutionary pathways of SCs in the last decade.

4. Contextual variables

Many variables might impact the willingness of city councils and city managers to implement SC projects. In this study, five groups of contextual variables are identified, namely: structural, economic, technological, environmental and social ones. Contextual variables are not related to a single project *per se*, but rather to the urban context wherein an initiative is developed [67] so that these can play a crucial role in an extended SC initiative or program. In the next sections, these variables are presented to underline why they are selected and how they are expected to influence the development trends of a SC.

Table 1
Classification of SC application domains and associated sub-domains.

Domains	*Sub-domains*	*Definition*	*Reference*
Natural Resources and Energy	Smart Grids	Systems aimed at providing power supply and usage more efficiently by adding intelligence to power generation and distribution, through the integration communications and control technologies	[45]
	Public lighting	New technolgies in public street lightning such as the adoption of LED can reduce the energy consuption and at the same time improve the visibility of pedestrians, cyclists and drivers	[46]
	Green/renewable energies	The use of energy from renewable sources – wind, biomass, hydro and solar power - is crucial for achieving a general reduction of energy consuption	[47]
	Waste management	It is a concern for modern cities due to both the operations related to the waste collection and the environmental issues of landfills. Innovative technologies seems promising solutions for handling waste collection and recovery operation in SCs	[48]
	Water management	In this field the integration with innovative technologies can be exploited for monitoring, finding anomalies and the data can be useful in water distribution network efficiency and effectiveness	[49]
Transport and mobility	City logistics	It can be defined as a comprehensive approach to make the first mile and last mile logistics services more organized and to mitigate the negative impacts of freight distribution	[50]
	Infomobility	It represents network system mainly characterized by connections, both digital and physical to reduce congestion and carbon emissions	[51]
	People mobility	The urban mobility of citizens is more sustainable by using alternative energy sources, soft transport systems and by optimizing public transports services	[52]
Buildings	Building services	The efficiency of the buildings' systems (electricity, water, air) play a crucial role in enhancing the building performance	[53]
	Facility management	It refers the real estate security, the operations and the maintance of a buildings. The advancement of technology and automation allows to a more proper usage of resources	[54]
	Housing quality	It represents the capability of providing high levels of	[55]

(*continued on next page*)

Table 1 (*continued*)

Domains	*Sub-domains*	*Definition*	*Reference*
		quality for occupants, by meeting their different needs over time	
Living	Pollution control	Smart sensing units and any data-driven techniques is able to perform more correct pollution control activities in the nowadays cities	[56]
	Public safety	Systems for surveillance, detection and identification, improved by using new technologies such as Big Data	[57]
	Health Care	The application of technologies such as IoT supports the integration of medical devices and improve the way physicians can deliver care. Also it boosts patients' satisfation by facilitating their interaction with doctors	[58]
	Welfare services	It is intended a greater state involvement for promoting and supporting social policy goals	[59]
	Public spaces	This aspect is related to importance of creating spaces for social interaction. In several case these areas refer to urban conversion of industrial sites	[60]
Government	E-government	It is based on the engagement of the citizenery in government in used-centerd manner. Operations and services are delivered so that to be tailored for the citizen's needs	[61]
	Procurement	The exploitation of ICT may be used to improve procurement processes in terms of more precise forecasting of demand for public utilities, controlling irregularities, and risks	[62]
	Transparency	Initiatives aimed at making decision-making processes more transparent improve the quality of the services that are delivered and reduce the related costs	[63]
Economy and people	Innovation and enterpreneurship	It represents the impact of innovative technologies on the way entrepreneurial initiatives are developed, in terms of integration among the assets, scaling and evolution of new ventures	[64]
	Entertainment and culture	These aspects, related to the issue of the knowledge economy are very important, because they stimulate flexibility, collaboration and tollerance among citizens	[7]
	Human capital	It fosters human capital development opportunities as a way to support the knowledge	[54]
	Education and school	Higher shares of citizens with higher education are likely to better support the growth of smart urban areas. In this sense, programs of education and school become relevant	[40]

4.1. Structural variables: size and demographic density

The city size can be crucial for the development of a SC initiative: big cities are able to attract more human capital [68] and public authorities often allocate resources based on city size [69]. Similarly, densily populated urban centers call for more SC projects to deliver services and infrastructures more efficiently [70]. Also, large and dense cities facilitate the sharing of knowledge and ideas by putting a greater number of people in contact and easing social interactions [71]. Thus, density and size can be considered as key features of modern areas [72]. Accordingly, the population can be considered as a significant variable in the development of SC patterns [7].

4.2. Economic variables

The Gross Domestic Product (GDP), which is an expression of wealth, is positively associated with the smartness of cities [73] In particular, higher GDP rates allow to get more financial resources available for investments in transportation, utilities, ICT and education [17]. Also, cities with greater growth rates are likely to attract those who want to enhance their life standards and who could in turn contribute to increasing the smartness of an urban enviroment [74,75].

4.3. Technological variables

The adoption of innovative technologies such as fiber optics, sensors and connected devices, open data analytics, and Internet of Things could significantly support the level of smartness of a city [24]. These technologies are used in both paths followed by SCs. The soft domains direction (education, culture social inclusion, social innovation) [5] and the hard domains one (buildings, energy, mobility) [17]. In the proposed analysis, the Global Innovation Index (GII) is taken into account as it is a suitable indicator for the evaluation of the innovative potential in socio-economic systems [76]. GII data consider 126 countries all over the world, equal to 90.8% of the global population and to 96.3% of the global GDP. By using 80 indicators it is able to get a large view related to the level of innovation in different fields such as politics, education, infrastructural, and digital agenda [77] Also, the diffusion of internet access among the local population can be relevant in faciliting the enactment of SC initiatives [17]. These issues have become dramatically crucial to be addressed, especially since the IoT applications are acquiring more and more importance in the interconnection of physical objects embedded with electronics, software, sensors and networks ([1].

4.4. Environmental variables

The complexity and relevance of the environmental issues in nowadays cities is one of the global grand challenges for the XXI century [78]. In fact, cities consume about 75% of the world resources and account for 80% of greenhouse emissions and they have serious impacts on environmental conditions [79]. Sustainable enviroments are better able to provide citizens with proper urban living quality by promoting green energy minimal consumption practices [80]. In our dataset, PM10 emissions have been taken into account because these are often considered when measuring the level of pullution in urban areas. This parameter has also received particular attention by the European Union that has fixed limit value in order to guarantee the right of clean air to its citizens [81]. Therefore, it is expected that low levels of PM10 are associated with a higher tendence in implementing SC projects that often generate environmental benefits. However, an opposite behaviour could be observed in the sense that more polluted cities are now developing projects aimed at improving the [82].

4.5. Social variables

Since cities are the engine for socio-economic development, more advanced environments might more easily ensure high employment rate [65]. In fact, the path of modernization and wealth involve reducing inequalities, poverty, homeless and unemployment [83]. Also, comparative to conventional cities, SCs serve human to use and grow their potential to live a quality life. Consequently, competent and better educated citizens are more likely to gather around a SC [22]. Low unemployment rates can be considered significantly related with the notion of SC and they are likely to have a positive impact on the willingness to develop SC initiatives. Finally, the amount of GPD invested in education might strenghten the SC development. As a matter of fact, it is crucial for cities to focus on increasing competencies and qualifications of the population, emphasizing the need for a better education and promoting creativity [84]. These aspects also play a crucial role in creating a well-trained workforce capable of accepting and interacting with innovative solutions for their cities [85].

5. Dataset

The analysis is carried out on a sample of 83 cities that declare to have carried out SC projects in one or more of the SC domains and subdomains given in Table 1 from 2013 to 2018. 32 cities are located in Europe, 20 in Asia, 19 in North America, 5 cities in South America, 4 in Oceania, and 3 in Africa. The proposed index has been defined as a proxy for assessing the level of smartness of a city. This index has been applied in the study proposed by [17] for assessing the trends in the adoption of SC projects worldwide. It is here considered as the dependent variable in a correlation analysis with the aim of assessing the impact on the willingness of investing in smart initiatives of social, geographic, demographic and environmental variables. In fact, as already mentioned a variety of factors are likely to influence the way cities decide to undertake SC initiatives. In Table 2 the variables taken into account are listed together with the main descriptive statistics and their related sources of open data.

Analysis and interpretation of results

Fig. 1 reports the number of SC projects associated with the six domains indentified in the study. In particular, the reported figures equal the binary sum variables of the projects carried out by each city in all domains and subdomains. The domains that record the greatest number of smart initiatives are Living, and Natural Resources and Energy. Similarly, SC projects carried out in the Natural Resources and Energy are largely implemented, which shows the crucial role played by renewable energy, energy efficiency and environmental impacts in exploiting energy sources.

Government is the domain for which the cities included in the sample report the lowest level of interest. This might be due to criticisms, such as administrative burdens, of public authorities in developing smart government initatives

Same analysis is performed at the sub-domain level in order to identify the fields of application that more heavily attract SC initiatives. The results are illustrated in Fig. 2.

From the point of view of a single sub-domain analysis, the Infomobility and People Mobility sub-domains are of great interest to municipalities. This demonstrates the attention given to urban mobility projects as an important lever to improve the average travelling time, traffic congestion and pollution [44].

On the contrary, Living & Natural Resources and Energy are made up by five and four sub-domains respectively. Also, a lot of initiatives related to the pollution control can be observed, in the light of the important role played by the air quality issue in the enhancement of the level of smartness for a city.

Finally, many projects can be found in the Public Space sub-domains. In fact, providing space for leisure, where people can meet up, but also space for entrepreneurship and innovation for promoting networking and collaboration is considered more and more important for a SC [86].

On the contrary, 22 projects are carried out in the Facility Management sub-domain, since this sub-domain mostly related to data sharing for improving the operations of buildings is relatively new and thus it could be more exploited in the next future [87].

Also, only a few projects have been carried out in the Procurement sub-domain. In this sense, public administrations are still hesitant in changing their traditional functions in order to adapt urban administrative structures into the new paradigm and, in turn, to enhance the smartness of their processes [83].

5.1. Factor analysis and coverage index

With the aim of identifing high-level factors, a factor analysis is applied at an exploratory level. This method is broadly used to obtain a classification of the data, in the sense that correlated measured variables are expected to reflect the presence of a smaller number of hidden underlying factors [88].

The results of the Factor Analysis are shown in Table 3. Three factors result from the analysis. 62.38% of the variability results explained by the model. As far as a reliable model is able to understand a percentage of variance from 50 to 60% [89], our analysis can be considered as consistent.

Trasport & Mobility and Living domains are grouped together in Factor 1, named as “Daily Management of Urban Environment”. The correct organization of public transport is likely to improve the quality of life of citizens especially in terms of pollution and usability of public spaces. Also, effective public transports represent an important element of public services for the livibility of urban enviroments [90].

Buildings and Natural Resources and Energy are related to Factor 2, named as “Environmental Impact”. Buildings require a high level of energy consumption due to heating, cooling and lighting in both commercial and residential sectors [91]. Thus, smart buildings that exploit innovative technologies can ensure an effective resource management and the reduction of their emissions [92].

Factor 3, which we define as “E-Democracy”, encompasses Government and Economy and People domains. This factor underlines the crucial role of ICTs in public adiministrations and their consequent influence on growing skilled human capital, on education, and

Table 2
Local context variables: descriptive statistics and literature source.

Contextual Variables	Variable	Unit	Mean	Min	Max	STd. Dev.	Source
Structural size and demographic density	City_area (km^2)	squared km	1,372.72	18	17,174.4	3,028.53	Wikipedia
	Density (pop./km^2)	# inhabitants/ squared km	5,952.61	142	21,423	5,265.19	CountryEconomy
	Population	# inhabitants	4,206,012.55	54,264	21,707,000	5,502,398.91	CountryEconomy
Economic	GDP ($BN)	$BN	220.15	2.92	1,893	310.05	CountryEconomy
	GDP per capita	$BN/# inhabitants	85.32	5.36	379.37	71.97	Monetary Fund
Technological	Global_Innovation_Index (GII) 2	-	51.12	21.9	63.8	10.16	Globalinnovationindex
	Households with Internet access		0.84	0.40	0.99	0.12	Statista+
Environmental	PM10 Emissions (ug/m3)	ug/m3	36.17	7.00	292.00	47.49	AirToday
Social	Unemployment rate	%	0.06	0.009	0.26	0.05	CountryEconomy
	Country Education Expenditure/ GDP	%	0.13	0.02	0.25	0.04	CountryEconomy

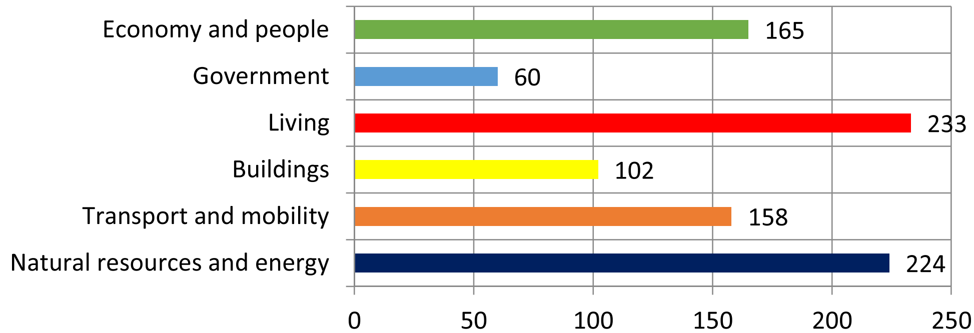

Fig. 1. Number of projects by domain.

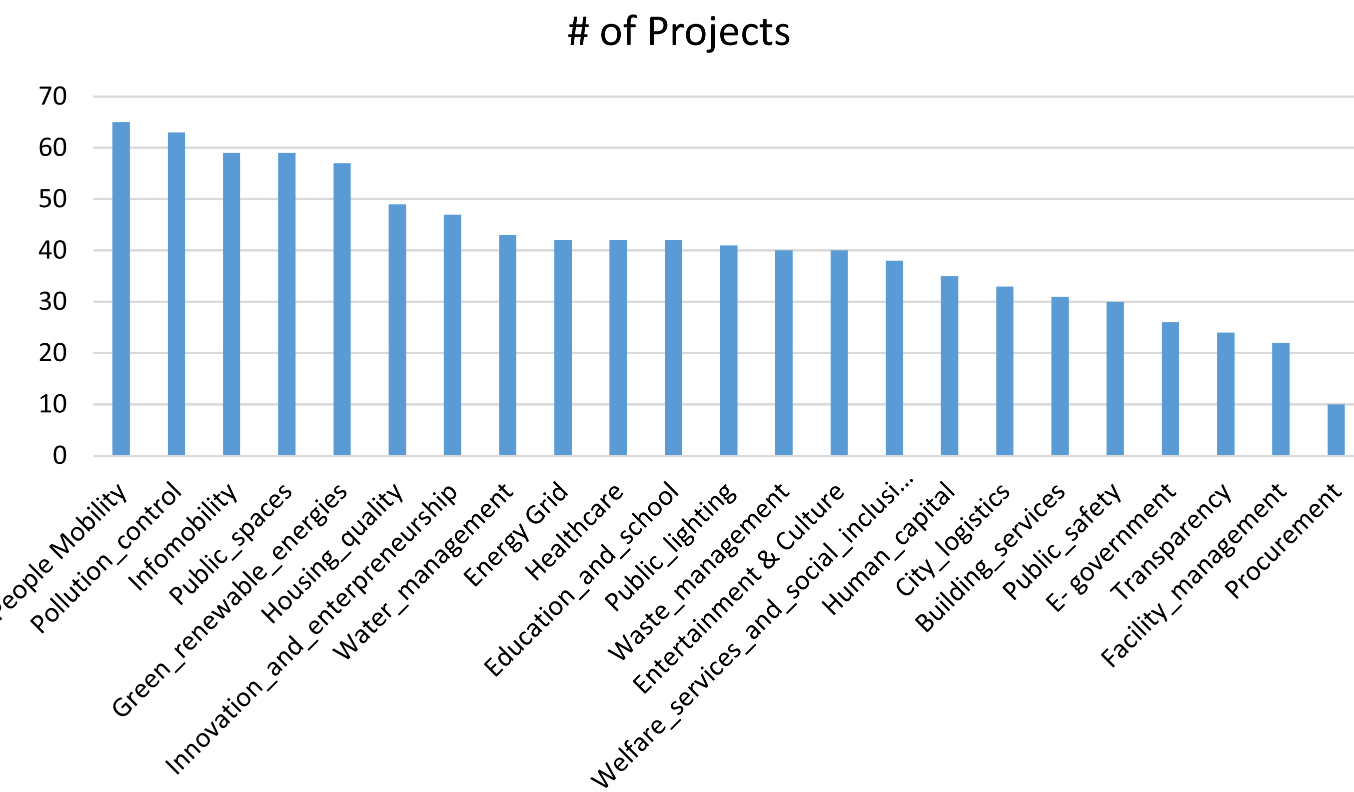

Fig. 2. Number of SC projects in each sub-domain.

Table 3
Results of factor analysis on SC domains.

Domains	Factor loadings		
	1	2	3
Transport and Mobility	**0,986**	-0,033	0,005
Living	**0,412**	-0,077	-0,171
Buildings	0,306	**0,795**	-0,236
Natural Resources and Energy	0,063	**0,227**	-0,336
Government	0,184	0,209	**0,251**
Economy and People	0,093	0,424	**0,697**

entertainment [93].

Also, the factor analysis is used to determine the relative importance of each measure with respect to each one of the six domains [934]. Thus, the weighted total summation is computed. Similarly, this calculation is carried out for all subdomains of the study. The CI is then computed as the weighted sum of the six indices related to the single domains. Thus, the CI refers to as the number of domains covered by SC initiatives developed by a city. It can be considered as a summary expression of the ability of a city to implement a comprehensive and large-span SC system with a wide spectrum of measures to include the different aspects of SC domains. The resulting weights for all domains and related subdomains are shown in Table 4.

The list of the CIs of the 83 sample cities is reported in the Appendix. Finally, by assuming CI to be a dependent variable, both an Analysis of Variance and a Correlation Analysis are conducted in order to capture the impact that the various external independent variables above may have in shaping a smart urban system.

5.2. Analysis of variance

The Analyis of Variance (ANOVA) is carried out in order to identify significant differences of the CI accross continents. This method is used to verify differences among the means of two or more groups [95] if its p-value is lower than the critical threshold of 5%, a significant difference among the groups can be asserted [96].

Table 5 reports the results of the ANOVA carried out with regard to the world region where a project is developed. A P-value lower than 5% indicates that there are significant differences in the willingness of

Table 4
Weights of each domain and subdomain.

	Natural Resources and Energy Grid	Public lighting	Green Renewable energies	Waste management	Water management
Weight in the Domain	0.0319	0.5399	0.0954	0.1076	0.2250
Absolute Weight	0.0066	0.1125	0.076	0.0224	0.0469
	Transport and Mobility				
	City logistics	Infomobility	People mobility		
Weight in the Domain	0.5857	0.3075	0.1066		
Absolute Weight	0.00258	0.0013	0.00046		
	Buildings				
	Building_services	Facility management	Housing quality		
Weight in the Domain	0.1465	0.3746	0.4788		
Absolute Weight	0.0555	0.1419	0.1814		
	Living				
	Pollution control	Public Safety	Healthcare	Welfare services and social inclusion	Public spaces
Weight in the Domain	0.0249	0.0819	0.1559	0.7275	0.0096
Absolute Weight	0.0052	0.0170	0.0325	0.1516	0.0020
	Economy & People				
	Innovation and enterpreneurship	Enterteinment and Culture	Education and school	Human capital	
Weight in the Domain	0.0171	0.1417	0.7804	0.0606	
Absolute Weight	0.0006	0.00496	0.0273	0.0021	

Table 5
Results of the ANOVA.

Analysis of Variance Source	Degree of Freedom	Adj SS	Adj MS	MS F-Value	P-Value
Geographical Area	5	0.8617	0.17233	2.58	0.033
Error	77	51.481	0.06686		
Total	82	6.0098			
Means					
Geographical Area	N	Mean	St Dev	95% CI	
Africa	3	0.2731	0.0935	(-0.242;0.5703)	
Asia	20	0.6687	0.2534	(0.5536; 0.7839)	
Europe	32	0.5529	0.2490	(0.4619; 0.6439)	
North America	19	0.4960	0.4960	(0.3778; 0.6141)	
Oceania	4	0.4884	0.0972	(0.2310; 0.7459)	
South America	5	0.3103	0.3103	(0.0801; 0.5406)	

investing in SC initiatives all around the world. In particular, both in Africa and South America the concept of SC has not been fully addressed, as shown by their low CIs. The weakness of systematic regulation (e.g. environmental regulation) in the areas might slacken the implementation of SC initiatives. In fact, legislations and regulations are important elements in enforcing SC strategies [52].

On the contrary, Asia and Europe show higher values of the CI, which means that in these continents there is a greater sensibility and awareness of the SC issue. In particular, the dramatic growth that megacities are facing in Asia calls for smartness in order to limit their environmental impacts and provide their citizens with a liveable context [36]. European cities are considered leaders in the field of SC developement [34]. They heavily invest in SC programs for different reasons, compared with the Asians ones. The European urban structure is made up by old cities with fragile and narrow streets and a historical and cultural heritage that needs to be protected [94]. In this context, SC projects can effectively preserve these urban areas.

5.3. Correlation analysis

In Table 6, the linear correlation analysis between the CI and the contextual variables is given to capture possible relationships between the type of SC initiative and the local factors that may shape its structure and implementation caracteristics. Both the Pearson Coefficient r and the associated p-value are given for all context variable associated to each SC domain. The Pearson Coefficient is the expression of the level of dependence between the CI and local context variables. It ranges from -1 to 1: it equals +1 in the case of a total positive linear correlation, -1 in the case of total negative linear correlation, and 0 in the case of no linear correlation [96]. The reliability of the relationship is represented by the p-value, which spans from 0 to 1 and indicates the probability of rejecting the null hypothesis. The significance level of the correlation, which typically equals 0.05, represents a constant critical value. If the p-value is smaller than the given critical value, the null hypothesis is rejected and it can be concluded that the relationship is significant. On the contrary, if the p-value is greater than the critical value, the test fails to reject the null hypothesis and it can be concluded that there is not enough evidence to prove a significant relationship [97]. The effects of independent variables are considered at two different levels: by taking into account the coverage of all the domains identified, and then via exploring the influence on every single domain.

From the results of the analysis given in Table 5, several significant correlations can be observed. Firstly, the CI is negatively correlated with the City Area and positively influenced by the GII. This means that SC initiatives are likely to be more easily implemented in small cities that are more willing to invest in innovation and new technologies. Small cities are still more able to better manage, monitor and control ICT projects. Also, small urban environments facilitate communications and the consequent awareness among citizens related to the importance of implementing SC projects. Not surprisingly, those cities that are more innovation-oriented are more willing to launch SC programs.

Secondly, a negative relationship between the GDP per capita and the CI in the Natural Resources and Energy domain can be observed,

Table 6
Results of correlation analysis.

Context variable		Coverage index	Natural resources and energy	Transport and mobility	Buildings	Living	Government	Economy and people
Population	**r**	-0.049	0.041	-0.185	-0.075	**-0.215**	-0.144	0.016
	p-value	0.656	0.711	0.094	0.498	**0.05**	0.194	0.888
Households with Internet access	**r**	0.115	-0.015	-0.146	-0.124	0.063	-0.105	-0.067
	p-value	0.299	0.891	0.189	0.263	0.572	0.347	0.548
Country Education expenditure G	**r**	0.140	0.114	-0.04	0.002	0.193	0.061	0.039
	p-value	0.203	0.303	0.969	0.984	0.08	0.581	0.724
City area (kmˆ2)	**r**	**-0.224**	0.07	0.013	-0.015	-0.059	0.152	0.005
	p-value	**0.04**	0.528	0.909	0.896	0.599	0.17	0.964
Density (pop./kmˆ2)	**r**	0.182	-0.16	0.027	-0.136	0.016	**-0.225**	-0.078
	p-value	0.098	0.148	0.808	0.219	0.889	**0.041**	0.482
PM10 Emissions (ug/m3)	**r**	-0.046	-0.06	-0.121	-0.161	**-0.345**	-0.032	-0.189
	p-value	0.677	0.957	0.276	0.146	**0.001**	0.777	0.086
GDP ($BN)	**r**	0.078	0.053	0.067	-0.0008	0.088	**-0.218**	0.06
	p-value	0.481	0.634	0.549	0.944	0.431	**0.048**	0.593
GDP per capita	**r**	-0.087	**-0.216**	0.036	-0.075	-0.068	0.063	-0.106
	p-value	0.431	**0.05**	0.749	0.502	0.544	0.571	0.34
Unemployment rate 2017	**r**	0.017	0.135	**-0.291**	**-0.282**	0.075	-0.098	0.093
	p-value	0.878	0.224	**0.008**	**0.01**	0.499	0.38	0.402
Global Innovation Index (GII) 2	**r**	**0.264**	-0.11	-0.12	**-0.221**	0.044	-0.185	-0.046
	p-value	**0.015**	0.324	0.28	**0.044**	0.692	0.095	0.681

indicating that richer urban environments are now more reluctant to invest in innovative SC projects. This result could be due to the starting level of this analysis. In fact, richer cities are likely to have already implemented projects tacklying the energy efficiency issues in past. Thus, such projects are now attracting more the attention of the less wealthy cities.

Thirdly, the Unemployment Rate is negatively related to Transport and Mobility projects. In fact, work commuters usually generate a large share of urban mobility demand [99]. Accordingly, the higher the number of unemployed citizens, the lower the demand for urban mobility, and, in turn, the lower the need to develop innovative programs in the Transport & Mobility domain. Similarly, the Unemployment Rate negatively influence the willingness to invest in the Buildings domain, which could be explained by a lower average level of family income.

Fourtly, the Buildings domain is also negatively affected by the GII. This result might be due to the fact that home automation systems have reached an adequate level of maturity in terms of innovation.

Then, Living is negatively correlated with Population and PM10 emissions. Megacities with a lot of inhabitants are dealing with problems in implementing smart Living projects. In particular, it appears very difficult for cities with millions of people face safety issues and managing Health Care facilities and services, because of the complexity in connecting many people together by expoloiting the latest technologies [97]. Polluted cities also encounter more difficulties in creating liveable enviroments [98]. Viceversa, low PM10 emissions determine more liveable urban areas. The process related to the enhancement of the air quality requires a relevant engagement and consequently a certain number of years to be completed. Therefore, the current projects in this field of application are still ongoing and their effects will be probably measured in the next future.

Finally, the Government domain is negatively influenced by Density and GDP, for low populated areas are facilitated in developing e-government, digital procurement, and transparent administration.

In small cities, relationships with the citizenship are easier to be implemented due to the lower related level of complexity. Low GDPs do stimulate projects in the Government domain. This is probably due to the fact that poor urban environments need to implement transparency programs aimed at increasing the efficiency of public processes in order to increase the attractiveness for private investors.

Furthermore, it highlights that Economy and People related projects based on entrepreneurship, culture and education are independent respect to the enviroment wherein these ones are carried out. Thus, it is difficult to find some trends out in this domain.

6. Discussion about the current trends

The results that are obtained by analyzing the data from 2014 to 2018 can be compared to the outcomes of the study by Neirotti et al. (2014), who investigate previous SC trends from 2009 to 2013. This comparison serves the purpose of capturing possible SC evolutions over the last decade.

Firstly, the present study shows the geographical influence on the level of smartness. This result was also in Neirotti et al. (2014): it can be stated that each area of the world addresses its own SC strategy based on available financial resources, cultural background and intrinsic development level.

Then, the current concept of SC is likely to be better tackled by small cities that can more easily implement SC programs in their territories. The population density, that proved to positively affect the CI in [17] is now independent meaning that that past relationship has not been confirmed in this more recent analysis. Thus, large cities that do not necessarily have high population density are struggling to implement SC programs. In addition, it appears difficult for more populated cities to carry out SC initiatives in the Living domain. A lot of challenges are still faced by highly populated cities, especially in terms of public safety and availability of livable public spaces.

The result proving that wealthier urban environments are more reluctant to invest in innovative SC projects apparently goes against [17].In fact, in that analysis higher levels of GDP per capita proved to stimulate more SC initiatives in the Energy sector. However, both results can be read together, in the sense that more developed cities have already launched SC investments in the past so that in recent years the need for developing new projects is likely decreasing.

The Unemployment Rate shows a significant impact on the Transport and Mobility domain. The population density that was a driver in the past is not correlated anymore to this domain. This result is aligned with the analysis carried out by [43] focusing on the studies of urban city logistics projects in Europe.

From 2009 to 2013 the Building domain was not able to attract a lot of attention by SC promoters. In more recent years it is significantly correlated to the Unemployment rate and to the GII. In fact, with lower employment rates the number of people that can afford new apartments in innovative buildings decrease, and so does the level of investment in smart buildings. Moreover, the high levels of innovation already achieved by the construction industry can be considered the result of low levels of recent investments in this domain. In other words, these results might reflect that the construction industry has reached an adequate level of innovation and stock of investment in smart buildings [100].

The Living domain was not showing significant relationships with any contextual variable in [17].On the contrary, there is now a negative correlation with the number of citizens and the emission of pollutants. As already mentioned, this result might be due to the fact that high popoluated and polluted cities are facing more and more problems in designing liveable spaces.

The Government Domains was positively related with the GDP. Now, the relationship is negative, meaning that poor cities are trying to invest more for enhancing the quality of their service and recovering the gap with the wealtier cities.

The results for the Economy and People domain are confirmed, in the sense that there is no evidence of significant relationship able to explain its behavior, with the contextual variables taken into account in the analyisis.

Also, the number of city domains covered by smart initiatives is positively correlated to their level of innovation. Thus, in general terms, innovation is a crucial driver for strenghtening the smartness of a city on all its fields of application.

It is important to underline that five out of six domains are impacted by at least one identified contextual variable. This demonstrates the validity of the variables selected for the analysis. Every kind of city faces probable strenghts and weaknesses in terms of developing initiatives related to the leisure, the culture and the education at the same time. Consequently, the present research might integrate with existing literature streams [17,43,100] by evaluating the new current trends characterizing the notion of SC.

An important aspect that deserves attention is related to several studies affirming that the high expectations related to the promising benefits of SCs have not been completely addressed. In particular, it is stated that many smart initiatives are merely ICT-based and the obtained benefits cannot be exploited by citizens' that are more and more interested by social and environmental issues. In this sense the results of the analysis cound confirm this idea. Outcomes show that the absence of a trend related to the Economy and People domain wherein social aspects are particularly relevant, shows that there is no pathway that drives their development. Also PM10 emissions prove to be a fundamental variable only for the Living domain, meaning that despite the strong debate on the environmental friendliness, the environment is not fully considered when launching and implementing smart projects in urban areas.

The global CI and the CIs for all domains are at least influenced by a context variable with the exception of the Economy and People. Such a result might depend on the fact that the initatives related to culture, innovation in education and human capital are not driven by a specific contextual variable.

In summary, SCs is a concept with large meaning intended to face social, economic and environmental challenges and improve the quality of life of their citizens in the era of pervasing ICTs, big data, information flows and the shared-economy systems.

This phenomenon could be explained through the hype cycle chart proposed by [101]. In particular, the hype of the SC notion has had a significant increase in terms of expectations in the past (*e.g.* peak of inflated expectations) and in the next few years this pattern is likely to reinforce. In particular, according to [102] it can be forecasted that SC applications will take from five to ten years to achieve the mainstream adoption and in turn move to the "trough of disillusionment" phase. In that phase the investments in SCs will be carried out if the promoters will be able to improve their products and services. This means that SCs, in the near future, should better respond to the demand for more efficiency by citizens and they should not be merely driven by new technologies *per se*.

Thus, it can be reaffirmed that the notion of SC is still not fully established. Several trends can be identified at the domain level. Some of them have been confirmed in comparison with previous studies, but some evolutions are still observed. from 2009 to 2013, SCs were more focused on developing projects in the hard domains such Buildings, Transport and Mobility, and Energy. On the contrary, now a lot of attention is given to projects in the soft domains of a SC as the significant relationship with the Living domain demonstrate.

Finally, the SC evolution pathway can be confirmed according to the Gartner cycle. In fact, it seems that big cities are less willing to implement smart projects. This might be due to the fact that they have already launched a number of SC projects, overtaken the peak of expectations and they are going to undertake the trough of disillusionment phase. On the contrary, the interest shown by small cities is at its peak of expectation phase wherein a lot of successful projects still attract capital investment.

7. Implications

This work originates several theoretical and practical implications. From a theoretical point of view, it can stimulate research to identify the most recent trends in different areas of SC implementation. In this sense, a revised taxonomy of the domains of a SC together with their most relevant associated sub-domains, based on recent literature is proposed. Moreover, it emphasizes the importance of academic contributions to extend the body of knowledge in this research area.

This work also integrates a stream of research claiming that the SC paradigm has, at least partly, failed to meet most of its expectations. In particular, the Government domain, mainly related to the public governance processes, is still little explored. Also, the absence of significant relationships between the Economy & People domain and the context variables demonstrates that there is not yet a set of external conditions able to drive innovative, cultural and educational SC programs.

From a practical perspective, the present study offers a structured framework to assess the level of smartness of a city and to understand the extent to which SC programs are developing in each domain and subdomain. With this point of view, the CI is a benchmark for city managers and public institutions to position the smartness of their city and, consequently, to design and carry out appropriate SC programs for effectively enhacing the sustainability of selected urban domains. In fact, the proposed CI underlines the importance of each domain and associated sub-domain, in a way that investment programs addressed to relevant domains allow to obtain a higher CI.

Also, this study has proven some significant relationships between several contextual variables and some domains. With this regard, policy makers, based on the caracteristics of their city, might identify those SC projects that can more easily increase the level of smartness in specified domains. For example, larger cities are called to invest in programs that improve the living domain, via supporting projects of pollution control, public safety, health care, welfare services, and public spaces.

Also, through the analysis of the contextual variables it is easier to identify the main levers that might facilitate the development of projects aimed at increasing the smartness of a city.

In addition, this work might be used as a standard to measure the actual level of smartness of a city. To do that, one has to use the weighted summation formula where the weights result from the presented factor analysis (see Table 4) and the addenda are the projects that a city carries out in each identied domain and subdomain.

Finally, this study could be used as a support to define SC strategies and to undertake the most appropriate actions. In fact, to effectively increase the level of smartness, a policy maker can easily direct investments and facilitate projects in those domains and subdomains that have a high relative weight.

8. Conclusions

This work contributes to the research stream in the SC field so as to capture the evolution pathways and most recent trends of SCs. To this end, based on literature research, six different domains and the associated sub-domains are identified, namely Natural Resources and Energy, Energy, Transport and Mobility, Buildings, Living, Government, and Economy and People. A CI is obtained as the ratio of the city's number of smart projects to the total number of identified domains and sub-domains. A group of contextual variables are identified and correlation analyses are carried out in order to capture significant relations between the CI and the structural, economic, technological, environmental, and social variables.

The results of the statistical analysis show that there is still not a comprehensive defined evolution pattern of the SC paradigm. In particular, the different areas of the world seem to follow their own strategy in developing SC programs. Overall, in this varied context, it is worth to underline that innovative and small urban areas are likely to stimulate SC programs. In particular, small cities with low levels of pollution and high technological orientation that are likely to address sustainable projects, can be considered as laboratories and incubators for the implementation of the recent enabling technologies in urban smart initiatives. Also, the rate of employment and the wealth per capita proves to be a significant lever in the development of SC initiatives.

However, this study does not consider life quality indicators aimed at evaluating the impact that SC initiatives have generated. Also, the analysis does not take into account the economic value that each SC initiative of the sample has created. For these reasons, future studies will be conducted towards the measurement of the impact of SC projects and the assessment of urban SC programs. In particular, it would be beneficial to establish a set of appropriate performance indicators and a measurement metrics to quantitatively and retrospectively assess the impact of the implementation of such programs.

Finally, it may be worth considering the impact of the Covid-19 pandemics in future SC studies. For instance, smart working, and online education and entertainment have changed and spread out with a consequent need for high speed and reliable internet connection in private houses. At the same time, the number of commuters has significantly decreased, with a lower demand for urban mobility. Also, the time spent at home has heavily increased, changing the requirements of citizens that in the future might prefer more spacious environments not necessarily in the city centers. Thus, it will be interesting to study the influence of these new unexpected behaviors on the different SC domains, especially in the Buildings, Transport and Mobility and Economy and People ones.

Declaration of Competing Interest

None.

Appendix. List of the Cities and their related Coverage Index

Cities	Coverage Index	Cities	Coverage Index
New_York	0.991	Parades	0.445
Hong_Kong	0.990	Melbourne	0.443
Suwon	0.984	Chicago	0.442
Austin	0.984	Los_Olivos	0.440
Amsterdam	0.972	Birmingham	0.433
Madrid	0.960	Riverside	0.428
Helsinki	0.951	Rio_de_Janeiro	0.415
Copenhagen	0.944	Curitiba	0.403
Manila	0.933	Oulu	0.401
Toronto	0.916	Kawasaki	0.400
Vienna	0.916	Växjö	0.388
Ottawa	0.900	Reykjavik	0.385
Singapore	0.895	Adelaide	0.383
Taipei	0.891	Delhi	0.381
Tokyo	0.869	Genoa	0.379
Bangkok	0.826	Yokohama	0.375
Seoul	0.822	Guangzhou	0.370
Lyon	0.820	Dubuque	0.362
Jakarta	0.810	Pavia	0.361
Montreal	0.809	Vancouver	0.351
Milan	0.803	Turin	0.350
Mosca	0.782	Reggio Emilia	0.337
Kuala_Lumpur	0.759	Nuremberg	0.333
Parigi	0.753	Durban	0.327
Los_Angeles	0.749	Capetown	0.327
Aarhus	0.730	Nanjing	0.321
Abu Dhabi	0.683	Mannheim	0.318
Dubai	0.683	Calgary	0.309
Gothenburg	0.655	Detroit	0.307
Ho_Chin_Minh_City	0.646	Dublin	0.264
Tallinn	0.644	Las Vegas	0.259
London	0.625	Santander	0.249
Budapest	0.623	Ghent	0.212
Stockholm	0.615	Osaka	0.202
Perth	0.607	Recife	0.198
Quebec_City	0.588	Lagos	0.165
San_Francisco	0.566	St_Louis	0.156
Sydney	0.520	Malaga	0.139
Pechino	0.490	Seattle	0.125
Barcelona	0.460	Mexico_City	0.100
Eindhoven	0.447	Porto Alegre	0.096
		Normal	0.022

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