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Urban resilience and sustainable development policies

An analysis of smart cities in the state of São Paulo

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Abstract
Purpose – The purpose of this paper is to analyze the urban resilience capacity and its relations with the economic, social and environmental well-being in smart cities in the state of São Paulo (SP), particularly after the 2008 financial crisis.
Design/methodology/approach – Concerning its objectives, this study is characterized as descriptive. From the point of view of technical procedures, the research is bibliographic, and regarding data collection, it is documental. The approach of this research is quantitative, since it uses the statistical method. The sample was made up by 62 smart cities located in SP. The analysis comprised the period from 2010 to 2015.
Findings – The urban resilience pillars influence the economic well-being represented by the gross national product, in 58.8 percent, social well-being represented by the life expectancy of the residents of the smart cities, in 71.7 percent, and in environmental well-being indicated by CO_2 emissions, in 21.5 percent.
Research limitations/implications – They are related to the researchers' decision about the methodological design.
Practical implications – This study was limited to smart cities in SP listed in the RBCIH (Brazilian Network of Human Smart Cities), and may be extended to other cities in other Brazilian states.
Social implications – How resilience dimensions related to economic, social and environmental well-being such as poverty, food security, health, well-being, education quality, climate changes, and the like, were measured, which can be investigated in future research studies.
Originality/value – Despite its growing popularity worldwide, the urban resilience pillars and their relationship with human well-being in smart cities in the national context are little investigated, making this research original.

Keywords Sustainable development policies, Urban Resilience, smart cities
Paper type Research paper

1. Introduction
Urbanization has transformed the planet from 10 percent urban in 1990 to over 50 percent urban in just two decades (UNDESA, 2010). Although the urban areas (at least 50,000 inhabitants) cover less than 3 percent of the global surface, they account for 71 percent of

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global emissions of carbon (IPCC, 2014) and consume 80 percent of the world's resources (Arbolino, Carlucci, Cirà, Yigitcanlar, & Ioppolo, 2018).

In this scenario, the strong dependence on non-renewable resources increases the levels of greenhouse gas (GHG) emissions, including a large amount of carbon dioxide (CO_2), an element that accounts for global warming. As cities continue to grow, coping with uncertainties and challenges, such as climate changes, has become imperative, and urban resilience has become a widely discussed concept (Leichenko, 2011).

In this regard, there are two main ways to respond to climate changes: GHG mitigation and adaptation. While mitigation focuses on the source of climate change, adaptation deals with its consequences, and it should be noted herein that that the term adaptation was brought to the attention of the scholar community by United Nations Framework Convention on Climate Change, as agreed in Rio de Janeiro in 1992 (Schipper & Burton, 2009).

According to Rizzi, Graziano, and Dallara (2018), sustainable urban development, taken as the future ability of local systems to support human well-being, is closely associated with resilience. In this context, cities play a major role in the fight of climate changes and in the implementation of new, smart technologies, and such actions have been seen as key factors for the reduction of GHG emissions and for the improvement of energy efficiency in the cities. Such technologies must be smart, lean, integrated, economic and efficient in resources, with impacts not only on the environmental and financial sustainability goals but on the citizens' well-being too (Ahvenniemi, Huovila, Pinto-Seppä, & Airaksinen, 2017).

Ahvenniemi, Huovila, Pinto-Seppä, and Airaksinen (2017) consider that the increasing interest on the concept of smart cities and the need to cope with urbanization-related challenges resulted in diverse public and private investments on technology development and implementation. This can be seen in the large number of initiatives of smart cities, projects of city build out, i.e., city development plans, and co-financed public research projects. In this regard, smart cities have set big goals for a clean future, participating in actions and city networks such as the Covenant of Mayors, the Civitas Initiative, the Concerto and the Green Digital Charter (Ahvenniemi *et al.*, 2017).

Since 2009, the concept of smart city has been understood as the objective of any city, irrespective of its size, and since then it has expanded globally (Marsal-Llacuna, Colomer-Llinàs, & Meléndez-Frigola, 2015). The initiative was developed based on previous experiences of measuring environmentally friendly, livable cities, considering the concepts of sustainability and quality of life, with an important and significant addition of technological and informational components. In 2013, in Brazil, with the purpose of leading actions and goals throughout the country, the Rede Brasileira de Cidades Inteligentes e Humanas (Brazilian Network of Human Smart Cities) was created, which is shared by 350 of the Brazilian biggest cities (RBCIH, 2018).

These goals, according to Ahvenniemi *et al.* (2017), are sustainable urban development policies designed to support energy efficiency and reduce CO_2 emissions, which are the same goals set by the European Union for 2030. According to these authors, these policies are necessary to assist decision makers in moving toward the desired direction and deploy such policies at the operational level, and assess the progress of the cities in the pursuit of the desired goals.

From the view of the European Union (2011), the concept of smart cities supports the idea of environmental sustainability, whose main goal is to reduce GHG emissions in urban areas using innovative technologies. According to Rizzi *et al.* (2018), sustainability aspires to a persistent, equitable long-term well-being, which is summarized into the resilience dimensions.

Given the above and aiming to investigate urban resilience, herein defined as the cities' ability to respond to or use a negative event as an opportunity for change and development

(Graziano & Rizzi, 2016) as well as the sustainable development policies of smart cities, the following research question is proposed:

RQ1. Which is the urban resilience capacity and its relationship with economic, social and environmental well-being in smart cities in the state of São Paulo (SP)?

Thus, the aim of this study is to investigate the urban resilience capacity and its relations with economic, social and environmental well-being in smart cities in SP, after the global crisis in 2008.

This study is based on the justification that the impact of shocks and stresses that affect the development of systems is responsible for the growth of urban areas and urban population. The OECD (2016) ranked these tensions in various groups: industrial structural change, e.g., the relocation or closure of the main businesses in a city; economic crises, such as the 2008 financial crisis and the sovereign debt crises that have impacted the European Union since 2009. The responses of the cities depend on characteristics such as the structure of their economy, proximity to capital (OECD, 2014) and internationalization of the local economy.

In the cited context, Rizzi *et al.* (2018) emphasize that the number of people entering or leaving a city or town has an influence on the employment rate, taxable income and on the demand for public services. In addition, migration has a great impact on the society and economy, and social integrations have been a major challenge for local cities, considering that violence, crime, terrorism may represent critical shocks for the city. Likewise, natural disasters have a critical impact not only on the environment but on the economy and society of the urban system as well. Changes in leadership and any policy discontinuance are other stressors, which may affect the economic basis of a city and its social structure. Thus, any kind of shock in complex systems, such as the urban system, has economic, social, environmental and institutional repercussions (Rizzi, Graziano, & Dallara, 2018).

In this sense, an evaluation of the pillars of urban resilience and its relationship with human well-being and a consideration of the economic, social and environmental components may help provide a structured basis to foster the development of public policies and the support of practical decision making, making this research relevant.

2. Theoretical framework

2.1 Urban resilience

The etymological roots of resilience are in the Latin word *resilio*, which means to recover (Klein, Nicholls, & Thomalla, 2003). The meaning of resilience is malleable, allowing that the interested parties join around a common terminology without requiring them to necessarily agree on an exact definition (Brand & Jax, 2007). Such imprecision can make resilience difficult to operationalize or to develop indicators or general metrics (Pizzo, 2015).

The notion of resilience was first developed in the materials sciences, since materials have the physical property of returning to its original form or position after a deformation that does not exceed its elastic limits. From this meaning, the term has been used in different disciplines, but the first studies addressing the topic of resilience were related to research on environmental phenomena (Rizzi *et al.*, 2018).

The term resilience became popular with Holling (1973) and is defined as the capacity to adapt to shocks, reduce vulnerability and resist to adverse changes. According to its Latin root, resilience is the ability to leap back or rebound, the ability of an entity or system to recover its original form and position elastically after a disturbance or disruption of some kind (Simmie & Martin, 2010). Therefore, the wide use of the term in regional or urban applications refers to the idea of the ability of a local socioeconomic system to recover from a shock or disruption (Simmie & Martin, 2010).

To Leichenko (2011), urban resilience is generally linked to the capacity of a city or urban system to withstand a wide range of shocks and stresses, such as climate change.

According to Meerow, Newell, and Stults (2016), urban resilience refers to the capacity of a urban system and all its socio-ecological and socio-technical networks constituent of temporal and spatial scales to maintain or return quickly to the desired functions in the face of disturbance, to adapt to the change and rapidly transform any system that limits the current or future adaptive capacity. To Graziano and Rizzi (2016), urban resilience offers interesting views about the analysis of the cities capacities in responding to or using an adverse event as an opportunity for change and development.

There is a strong link between resilience and sustainability: sustainability captures the aspiration for persistent and equitable well-being in the long term, which is summarized in the resilience ability to persist and ability to adapt (Rizzi *et al.*, 2018). Sustainable development aims to create and maintain social, economic and ecological systems prospering from a co-evolutionary point of view. Both sustainability and resilience recognize the need for preventive measures for the use of resources and in relation to emerging risks, aiming to promote the integrity of future well-being (Rizzi *et al.*, 2018).

In this context, Dubé and Polèse (2016) evaluated the resilience of 83 Canadian regions using four metrics: population, employment, unemployment and employment rates. The results pointed to regional economies are generally responsive, with a wide range of reactions to recessive shocks, *a priori* compatible with the notion of resilience. However, the interval of responses observed, depending on the metrics used, the applied methods and contextual considerations, give rise to interpretations, and the evaluation serves as a laboratory for a reflection about resilience as a useful analytical concept in regional studies.

Di Caro (2017) investigated empirically the evolution of regional employment in Italy from 1992 to 2012, as well as the regional economic resilience. The results showed differences in the economic resilience of Italian regions, both in terms of robustness and variations in the national businesses cycle and the total impact of shocks on the growth of regional employment. The regional differences found in the economic resilience are explained by the presence of spatial interactions and the adoption of some determinants such as economic diversity, exports performance, financial constraints and human and social capital.

Rizzi *et al.* (2018) evaluated the concept of regional resilience adopting a holistic approach which distinguishes the three dimensions of sustainability (economy, society and environment) and outcome driver variables. One of the findings was that the map of European economic and social well-being is more intensive in the metropolitan regions of the capital cities and industrial areas, penalizing conversely the Mediterranean regions of the continent. Other finding was the positive relationship between the territorial outcome and the regional drivers of resilience, in which economic factors such as innovation, investment and human capital help explain the economic well-being level measured by the gross national product (GNP) per capita, considered as proxy of social well-being, as well as other factors such as low mortality rate and low unemployment level. Finally, the drivers of environmental resilience such as the high level of biodiversity and low level of artificial areas explain the good outcome in terms of low levels of GHG emissions.

Based on the information and studies presented, the interest is clearly shown in three main factors: fixed capital per worker; employment in science and technology, considered as the participation of active people employed in these industries; and human capital considered as the representativeness of graduate individuals, as described according to the following hypotheses:

H1a. There is a positive relationship between the gross fixed capital per worker and the economic well-being in smart cities in the state of São Paulo.

H1b. There is a positive relationship between innovation (science and technology) and the economic well-being level in smart cities in the state of São Paulo.

H1c. There is a positive relationship between human capital and the economic well-being level in smart cities in the state of São Paulo.

2.2 Sustainable development policies

Sustainable development policies in cities have as main goal to provide the basis and improvement of urban eco-systemic services that deliver human well-being to their residents. These services are enough and necessary for humans in urban systems and can be considered as most of the requirements for human well-being, being divided into economic, social, ecological and environmental components (Masnavi, 2007).

Opschoor (2011) emphasizes that one of the challenges that both society and policymakers must cope with in the twentieth century is to reconcile the economic and social needs of urban populations sustainably. So, to ensure equilibrium of their relationships with the environment, life support, regeneration and absorption systems on which the cities are dependent, it is necessary the transformation within the system of urban ecology economics for urban sustainability (Opschoor, 2011).

While many people still argue that social pressures and market mechanisms can help accomplish such reconciliation, the prevailing view is that it cannot be achieved without being supported by policies and governance. The policies that deal with sustainable urban development must cover various fields, such as urban rehabilitation, use of urban soil, urban transport, urban energy management (Opschoor, 2011).

In this context, the Conference on Environment and Development (Earth Summit) held in Rio de Janeiro in 1992 was one of the most important events in the context of sustainable development. Agenda 21 was one of the major outcomes of the Earth Summit, and this program represents a practical tool for application of sustainable development policies both locally and nationwide.

After the United Nations Millennium Summit in 2000, eight international development goals were established by the UN, such as the Millennium Development Goals (MDG), for instance. Government authorities of 189 UN member states agreed to accomplish the MDGs by the end of 2015. Subsequently, governments agreed to develop a set of universally applicable Sustainable Development Goals (SDG) based on the MDGs and which converge toward the post-2015 development agenda to promote focused and coherent actions according to the sustainable development discussed in Rio+20 conference held in 2012 (Rahdari, Sepasi, & Moradi, 2016).

The MDGs have produced a sound anti-poverty movement, serving as a springboard for the new agenda of sustainable development to be adopted by world leaders (United Nations, 2018). Since the Earth Summit Conference, the world has identified a new path for human well-being and sustainable development. The concept of sustainable development as introduced in Agenda 21 recognizes that economic development must be in harmony with a growth that meets the needs of people and protects the environment (United Nations, 2018).

The SDGs, which emerged in the Rio+20 conference on sustainable development, aim to improve the economic, social and environmental conditions, especially in less developed countries (Dhahri & Omri, 2018). The SDGs were adopted in 2015 by 193 members of the UN General Assembly as reference goals for the international development community for the period of 2015–2030. They highlight two priorities for protection of the life support system in Earth with reduction of poverty. The SDGs defend a triple bottom line approach to sustain human well-being, namely, economic development, environmental sustainability and social inclusion (Dhahri & Omri, 2018).

The triple bottom line approach was born of the idea that the social, environmental and economic pillars of sustainable development are closely interrelated and cannot be considered separately (Strange & Bayley, 2008). Therefore, a pure economic development must have some limits, since the achievement of sustainable development requires the integration not only of its economic dimension but the environmental and social dimensions too. If an economy focuses only on the economic dimension, then it would become a society with a higher GNP but also one which destroys the environment or disrespects the social rights of the population (Dhahri & Omri, 2018).

According to Serageldin (1995), the basic premise that leads to this idea is that every human activity is a sub-system of an ecosystem and, in fact, the human population and the activity that they produce are part of a larger whole, the ecosystem in which they evolve. This ecosystem includes the physical environment and all live organisms that share this space and interact in it.

The human activity depends on the ecosystem and its ability to maintain such activity. Some environmentalists take this rationale even further, with a view that human activity influences the ecosystem, and if the human development is not controlled, there will be irreversible changes that will put at risk its capacity to support the human activity (Serageldin, 1995). In this regard, Table I describes the SDGs about sustainable development.

These goals aim to transform current conditions of education, health, employment, pollution and poverty, among other world issues, particularly in developing countries (Rahdari *et al.*, 2016).

Along this line, some studies such as those by Dhahri and Omri (2018) investigated the entrepreneurship ability to simultaneously enhance economic growth, promote environmental actions and improve social conditions in developing countries. They found that entrepreneurship in developing countries contributes positively to the economic and social dimensions of sustainable development, while its contribution to the environmental dimension is negative. The results of the causality test confirm the interactions between entrepreneurship and these three dimensions in the short and long term.

Yan, Wang, Quan, Wu, and Zhao (2018) evaluated sustainable urban development based on the reality of natural resources constraints and human well-being needs, the performance

Goals	Description
1	End poverty in all its forms everywhere
2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
3	Ensure healthy lives and promote well-being for all at all ages
4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
5	Achieve gender equality and empower all women and girls
6	Ensure availability and sustainable management of water and sanitation for all
7	Ensure access to affordable, reliable, sustainable and modern energy for all
8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
10	Reduce inequality within and among countries
11	Make cities and human settlements inclusive, safe, resilient and sustainable
12	Ensure sustainable consumption and production patterns
13	Take urgent action to combat climate change and its impacts
14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation and halt biodiversity loss
16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
17	Strengthen the means of implementation and revitalize the global partnership for sustainable development

Source: Adapted from Dhahri and Omri (2018)

Table I.
Sustainable Development Objectives (SDO)

of sustainable urban development in Chinese cities as a case study. The results showed a rising trend in sustainability in the last three decades, with visible spatial differences and, when they evaluated the urban development of the society, economy and industry in China, the results indicated various characteristics and differences in urban development.

Based on these influencing elements on social well-being, four research hypotheses can be formulated, as follows:

H2a. There is a positive relationship between long-term unemployment rate and the social well-being level in smart cities in the state of São Paulo.

H2b. There is a negative relationship between crash fatality rate and the social well-being level in smart cities in the state of São Paulo.

H2c. There is a negative relationship between infant mortality and the social well-being level in smart cities in the state of São Paulo.

H2d. There is a negative relationship between the number of unemployed/uneducated people and the social well-being level in smart cities in the state of São Paulo.

Dhingra and Chattopadhyay (2016) emphasized that a smart city has goals to be achieved in an adaptable, reliable, scalable, accessible and resilient way, such as: improve the quality of life of their citizens; ensure economic growth with better employment opportunities; improve the citizens' well-being by ensuring access to social welfare services and assistance; establish an environmentally responsible and sustainable approach for development; ensure efficient basic services and infrastructure including public transportation, water supply and drainage, telecommunications and other utilities; capacity to address climate changes and environmental issues; and provide an effective mechanism of regulatory and local governance, ensuring equitable policies.

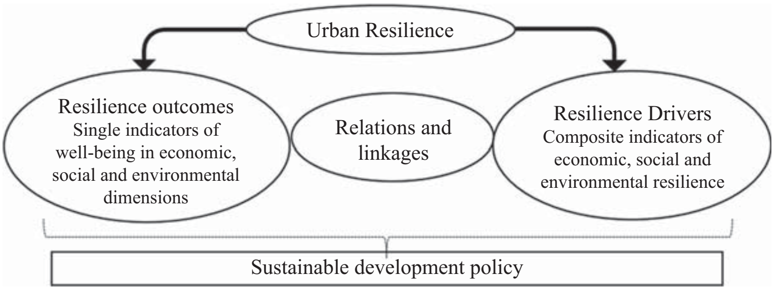
Technology is a tool that can facilitate the achievement of these goals. To Gordon and McAleese (2017), convergence of the city technology is commonly referred to as smart city, and such convergence is seen as a possible remedy for the challenges posed by urbanization in the era of global climate change and as a facilitator of a sustainable and livable urban future. In general, smart cities incorporate at least five parameters: smart governance and education; smart healthcare; smart buildings; smart mobility; smart infrastructure; smart technology; smart energy; smart citizens (Gordon & McAleese, 2017). The authors emphasize that, by using this integrated information, a smart city can improve the resilience of the power grid, prioritize road maintenance projects to meet traffic needs or make it easier to predict how crowds might react in an explosion or how a disease may be spread. In general, smart city projects can produce a range of reliability, predictability and efficiency benefits. Thus, based on the above theoretical assumptions, the following hypotheses are formulated:

H3a. There is a positive relationship between fixed capital per worker and the environmental well-being in smart cities in the state of São Paulo.

H3b. There is a negative relationship between artificial infrastructure and the environmental well-being level in smart cities in the state of São Paulo.

H3c. There is a negative relationship between the population growth rate and the environmental well-being in smart cities in the state of São Paulo.

Based on literature assumptions about urban resilience and sustainable development policies, the theoretical model of Figure 1 shows the relationships between the single indicators of well-being dimensions and the composite indicators of the resilience pillars, as idealized by the precepts that the social, environmental and economic pillars of sustainable development in smart cities are closely interconnected and cannot be considered alone.



Source: Adapted from Rizzi *et al.* (2018)

Figure 1.
Theoretical model

As in the study by Rizzi *et al.* (2018), it is expected a positive relation between urban outcome and the urban resilience drivers, where economic factors such as innovation, fixed capital and human capital help explain the economic well-being level measured by the GNP per capita; life expectancy, considered as a proxy of social well-being, which is associated with social resilience factors such as low mortality rate, low unemployment rate or social difficulties; and the environmental resilience drivers such as the high biodiversity level and few artificial areas, which explain a good ecological outcome, summarized in low level of CO_2 emissions.

3. Methodology

This is a descriptive, bibliographic and documental study (Richardson, 1999). The study examines the urban resilience capacity and the relationship between this capacity and the economic, social and environmental well-being of smart cities in SP after the global crisis in 2008. It was conducted in the context of smart cities in SP included in the Brazilian Network of Human Smart Cities (RBCIH, 2018). Thus, the sample of this study corresponds to 62 smart cities listed in the RBCIH, which provide data on the CO_2 variable. Data were collected in the first half of 2018 and corresponds to the period from 2010 to 2015 (Table II).

With the purpose of assessing 62 smart cities, Table III shows the variables that comprise the urban resilience pillars (economic, social and environmental) and the well-being pillars (economic, social and environmental), as represented by: GNP per capita, life expectancy and CO_2.

The economic resilience drivers can be attributed to fixed and human capital, innovation and entrepreneurship. The gross fixed capital per employee is a proxy of the availability of resources for the economic dimension (Briguglio, Cordina, Farrugia, & Vella, 2009), while the percentage of graduates in the population represents the educational dimension, working as an indicator of the availability of capabilities in terms of human capital (Jabeen, 2014). The variable related to the number of employees in the C&T sector describes the urban innovation system as key drivers of urban resilience (Chapple & Lester, 2007).

The social resilience factors are basically associated with social vulnerability. The indicator of traffic fatalities, long-term unemployment rate and the percentage of unemployed and uneducated population describes the extension of the social difficulties that affect adversely the ability of social systems to cope with a negative event (Glatron & Beck, 2008; Rizzi, Graziano, & Dallara, 2015).

The environmental resilience drivers are connected to quality and eco-systemic pressures. Biodiversity is an indicator of heterogeneity of the ecological structure, which positively affects urban resilience. In this study, this measure is referred to as greening or forestation (Schneiderbauer, Pedoth, Zhang, & Zebisch, 2013). Greening or forestation represents the provision of natural capital, trees planting, green spaces, increasing the

Order	Smart cities	Order	Smart cities	Order	Smart cities
1	Americana	22	Hortolândia	43	Santa Barbara d' Oeste
2	Amparo	23	Indaiatuba	44	Santa Gertrudes
3	Araçatuba	24	Itapevi	45	Santo André
4	Araraquara	25	Itaquaquecetuba	46	Santos
5	Barretos	26	Jacareí	47	São Bernardo do Campo
6	Barueri	27	Jales	48	São Caetano do Sul
7	Batatais	28	Jundiaí	49	São Carlos
8	Bauru	29	Limeira	50	São José do Rio Preto
9	Bebedouro	30	Marília	51	São José dos Campos
10	Botucatu	31	Matão	52	São Paulo
11	Campinas	32	Mauá	53	São Sebastião
12	Carapicuíba	33	Mirassol	54	São Vicente
13	Catanduva	34	Mogi das Cruzes	55	Sertãozinho
14	Cordeirópolis	35	Nova Odessa	56	Sorocaba
15	Cotia	36	Osasco	57	Sumaré
16	Diadema	37	Piracicaba	58	Suzano
17	Embu	38	Pirassununga	59	Taboão da Serra
18	Ferraz de Vasconcelos	39	Praia Grande	60	Taquaritinga
19	Franca	40	Presidente Prudente	61	Taubaté
20	Guarujá	41	Ribeirão Preto	62	Votuporanga
21	Guarulhos	42	Rio Claro		–

Source: Search data (2019)

Table II.
List of smart cities

availability of the necessary resources for regeneration of a territorial capacity (Schneiderbauer *et al.*, 2013). On the other hand, the variables of artificial infrastructures and population growth rate are proxies of negative anthropic forces about nature that affect the urban resilience capacity.

For data analysis, which was carried out using the Statistical Package for the Social Sciences software, version 21, the Pearson's correlation and Linear Regression procedures were used. The first step consisted of checking for variables that were strongly correlated between pairs for further exclusion. Subsequently, the normality of data was checked, which was met by the variables. Thus, the next section presents the descriptive statistical data, the correlation and respective regressions between the variables.

4. Results and discussions

The descriptive statistics of the variables are presented in Table IV.

According to Table IV, the GNP and CO_2 variables presented high descriptive statistics due to the scale itself. The high variability of these measures, given by the observation of the standard deviation, indicates that for GNP there are significant differences for the cities analyzed, due to the high totality of end products and services produced in the period studied. Regarding CO_2, there are cities with high emissions compared with others of this study. With respect to the citizens' life expectancy (average of 76 years), it is within the national average, which is around 75.8 years.

Before conducting the multiple linear regression analysis, the intensity and significance of the relationships between the variables were analyzed, by calculating the Pearson's correlation coefficient. It should be noted that the correlation does not necessarily implies the cause and effect relation, but, rather, the association between the variables. Table V shows the correlation between the variables.

We observed significant correlations among the variables studied. Thus, the associations with coefficients above 0.3 are emphasized, regardless of whether they are directly or

Pillars	Variables	Concept	Theoretical source	Source of data collection
Economic resilience	Gross fixed capital per employee (F.C)	Remuneration per employee quantified in minimum salary	Briguglio *et al.* (2009)	IBGE
	Employment in the S&T sectors (EMP)	Percentage of the active population employed in the science and technology sector	Sotarauta (2005), Chapple and Lester (2007)	SEADE
	Graduates in population (GRAD)	Percentage of graduates in the population	Sotarauta (2005), World Bank (2014)	Atlas Brasil
Social resilience	Long-term unemployment rate (EMP R)	Percentage of long-term unemployment (12 years or more	Naudé; McGillivray and Rossouw (2009)	Atlas Brasil
	Accident mortality rate (A.M.R)	It is the number of deaths per accident, in a period of one year, for every 1,000 individuals in the population	Glatron and Beck (2008), Rizzi *et al.* (2015)	SEADE
	Child mortality rate (C.M.R)	It is the number of infant deaths in a year, for every 1,000 individuals in the population	Tran, O'Neill and Smith (2010)	SEADE
	Rates of people without employment/ without educational background (R.W.E.E.B.)	Percentage of persons aged 18–24 who are not tied to a job or educational background	Shaw (2009)	Atlas Brasil
Environmental resilience	Afforestation (ARB)	Indicator of afforestation of cities (Trees as part of the ground cover)	IPCC (2001), Tran *et al.* (2010)	IBGE
	Urban areas (URB)	Percentage of residential, economic and infrastructure-related areas as a share of land use	IPCC (2001), Tran *et al.* (2010)	IBGE
	Population Growth Rate (POP.G)	Index of population growth that is the variation of the number of individuals, in the period of one year	Rizzi *et al.* (2018)	IBGE
Economic well-being	GNP per capita (GNP)	GNP per capita in purchasing power parity	Di Caro (2017), Yigitcanlar and Kamruzzaman (2018)	IBGE
Social welfare	Life expectancy (L.EXP)	Average life expectancy (projection of age in years)	Dallara and Rizzi (2012)	Atlas Brasil
Environmental welfare	CO_2 emission	CO_2 emissions per square kilometer of regional area	Yigitcanlar and Kamruzzaman (2018), Rizzi *et al.* (2018)	AEEESP

Source: Prepared by the authors (2019)

Table III.
Pillars of research

indirectly proportional. The directly proportional correlations considered moderate (between 0.3 and 0.6) were all significant at 1 percent, and they are: GNP and life expectancy ($r = 0.316$), fixed capital and CO_2 ($r = 0.330$), graduates and life expectancy ($r = 0.350$), greening and graduates ($r = 0.359$), greening and crash death rate ($r = 0.418$), urbanization and employment rate ($r = 0.321$). The indirectly proportional correlations were between crash death rate and fixed capital ($r = -0.416$), greening and employment rate ($r = -0.378$), population and crash death rate ($r = -0.576$) and population and greening

Variables	Minimum	Maximum	Average	SD
GNP[a]	10,681.7967	159,355.1767	37,946.8280	22,245.9316
L.EXP	74.6100	78.2000	76.2718	0.8175
CO_2	69.5917	14,154.4900	797.4354	1,944.8797
F.C	2.1000	4.6000	3.1032	0.5928
EMP	3.0300	48.4400	18.7160	8.1079
GRAD	3.7000	31.1900	13.7779	5.4746
EMP R	12.5300	56.0800	31.3577	8.4544
A.M.R	7.5900	29.7550	18.3947	4.7240
C.M.R	9.2400	16.8800	12.6913	1.6052
R.W.E.E.B	28.9400	49.7100	38.4248	4.0176
ARB	37.3000	99.2000	85.3323	13.1602
URB	11.0000	115.1000	42.9984	19.5096
POP.G	67.6217	12,698.1467	2,127.2730	3,195.7459

Note: [a]GNP data derived from 2010 to 2015. Deflated to 2010, INPC index
Source: Search data (2019)

Table IV.
Descriptive statistics

($r = -0.334$). Finally, the correlations considered strong (over 0.6) were found between fixed capital and GNP ($r = 0.635$), and infant mortality and life expectancy ($r = -0.820$). It should be noted that among the relationships previously found, all are in line with the expectations of associations.

After calculating the variables correlations, the regression analysis was carried out aiming at verifying the explaining factors of GNP, life expectancy and CO_2. Due to space limitation, we decided to put on the same table the results of regressions and their tests. The first one, Table VI, presents the results of the independent variables that represent the pillars (economic resilience, social resilience and environmental resilience) in the economic factor.

According to Table VI, the coefficient of determination (R^2) indicates that 58.8 percent of the GNP variance is explained by the variables that represent the pillars of economic, social and environmental resilience in the smart cities. The Durbin–Watson test showed a value close to 2, which enabled the verification of the independence of residuals, indicating that there is no relation between them (Maroco, 2007).

As for the results of the proposed hypotheses, it can be seen that the *H1a* (F.C. → GNP; β: 0.644; sig.: 0.000); *H1b* (EMP R.→GNP; β: 0.267; sig.: 0.023); *H1c* (GRAD→GNP; β: 0.252; sig.: 0.048) were all positively correlated, and statistically significant, with the economic well-being level of the smart cities. This indicates that these factors of the economic resilience pillar affect positively the economic well-being of the cities under analysis, which corroborate the findings of Dubé and Polèse (2016).

The results for the economic resilience pillar contribute directly to the following SDGs: (Goal 4) ensure equitable, inclusive and quality education and provide learning opportunities for everyone's lifetime; and (Goal 5) ensure gender equality and empowerment of all women (Dhahri & Omri, 2018), in addition to indirectly contribute to the other goals by providing the establishment of a scientific culture in the society, cooperating in the dissemination of knowledge and solutions (MCTIC, 2016).

In the sequence, Table VII presents the results of the variables regression analysis of the resilience pillars with the life expectancy of the residents of the smart cities in the state of São Paulo.

By means of the ANOVA test, there are evidence that the model variables have influence on the life expectancy. About the hypotheses, only *H2c* (I.M.R.→ LF.EXP; β: −0.796, sig.: 0.000) was significantly correlated, indicating what was expected: there is a negative relationship between infant mortality and the social well-being level in the smart cities in SP, i.e., the lower the infant mortality rate the higher the life expectancy of the population.

Table V.
Correlation of variables

	GNP	L.EXP	CO_2	F.C	EMP	GRAD	EMP R	A.M.R	C.M.R	R.W.E.E.B	ARB	URB	POP.G
GNP	1												
L.EXP	0.316**	1											
CO_2	0.085	−0.087	1										
F.C	0.635**	0.238*	0.330**	1									
EMP	0.084	−0.015	−0.122	−0.024	1								
GRAD	0.237*	0.350**	0.204	0.173	−0.283*	1							
TEMP	−0.048	−0.114	0.044	0.151	−0.282*	−0.100	1						
A.M.R	−0.057	−0.031	−0.253*	−0.416**	0.026	−0.069	−0.289*	1					
C.M.R	−0.349**	−0.820**	0.077	−0.188	0.008	−0.241*	0.154	−0.054	1				
R.W.E.E.B	−0.164	−0.027	−0.137	−0.195	0.232*	−0.201	0.074	0.304**	−0.005	1			
ARB	−0.013	0.170	−0.128	−0.161	0.259*	0.359**	−0.378**	0.418**	−0.120	0.174	1		
URB	0.163	0.035	0.058	0.232*	−0.116	0.187	0.321**	−0.114	0.121	0.088	0.056	1	
POP.G	0.084	−0.102	0.216*	0.182	−0.139	−0.132	0.278*	−0.576**	0.103	−0.246*	−0.334**	0.120	1

Notes: *,**Significant at the 0.05 and 0.01 levels, respectively
Source: Search data (2019)

	Non-standardized coefficient		Standardized coefficient		
	B	Default error	*β*	*t*	Sig.
(Constant)	−21,386,696	39,259,036		−0.545	0.588
F.C	24,150,086	3,990,503	0.644	6,052	0.000
EMP	731,796	311,292	0.267	2,351	0.023
GRAD	1,019,440	502,321	0.251	2,029	0.048
T_EMP	−115,859	292,743	−0.044	−0.396	0.694
A.M.R	2,148,860	641,107	0.456	3,352	0.002
C.M.R	−2,737,164	1,354,731	−0.198	−2,020	0.049
R.W.E.E.B	−560,344	575,990	−0.101	−0.973	0.335
ARB	−355,381	214,361	−0.210	−1,658	0.103
URB	92,545	117,981	0.081	0.784	0.436
POP.G	1,584	0.819	0.228	1,935	0.059
		ANOVA			
	Sum of squares	df	Medium square	*Z*	Sig.
Regression	17,738,468,381,799	10	1,773,846,838,180	7,267	0.000[a]
Residue	12,449,301,541,620	51	244,103,951,796		
Total	30,187,769,923,420	61			
		Model summary			
R	R^2	R^2 adjusted	Standard estimate error	Durbin–Watson	
0.767	0.588	0.507	15,623.826413413300000	1,951	

Note: [a]Significance at 1 percent level
Source: Search data (2019)

Table VI.
Regression with GPD

	Non-standardized coefficient		Standardized coefficient		
	B	Default error	*β*	*t*	Sig.
(Constant)	81,083	1,196		67,810	0.000
F.C	0.031	0.122	0.023	0.259	0.797
EMP	0.001	0.009	0.014	0.150	0.881
GRAD	0.015	0.015	0.101	0.984	0.330
T_EMP	0.000	0.009	−0.004	−0.041	0.967
A.M.R	−0.018	0.020	−0.102	−0.907	0.369
C.M.R	−0.405	0.041	−0.796	−9,826	0.000
R.W.E.E.B	−0.003	0.018	−0.013	−0.150	0.882
ARB	0.003	0.007	0.054	0.517	0.607
URB	0.004	0.004	0.104	1,215	0.230
POP.G	−1,637E−05	0.000	−0.064	−0.657	0.514
		ANOVA			
	Sum of squares	df	Medium square	*Z*	Sig.
Regression	29,219	10	2,922	12,903	0.000[a]
Residue	11,549	51	0.226		
Total	40,768	61			
		Model summary			
R	R^2	R^2 adjusted	Standard estimate error	Durbin–Watson	
0.847	0.717	0.661	0.47586	1,860	

Note: [a]Significance at 1 percent level
Source: Search data (2019)

Table VII.
Regression with Life Expectancy (L.EXP)

The result of *H2c* partially agrees with the findings of Dhahri and Omri (2018) and Rizzi *et al.* (2018), since the other hypotheses did not show a statistical significance. In this context, the result of the infant mortality rate indicator, which is part of the social resilience pillar, has influence on the ability of social systems to cope with an adverse event in smart cities in SP (Rizzi *et al.*, 2015).

Dhahri and Omri (2018) found that the entrepreneurship in developing countries affects positively the social and economic dimensions of sustainable development, while its effect on the environmental dimension is negative. This confirmed that the challenges of the sustainable development in developing countries correspond to a problem of prisoners' dilemma, where businesses/entrepreneurs are forced to experience an environmentally degrading behavior due to divergence between the individual rewards and the collective sustainability goals. The authors also emphasized that such findings confirm the interactions between entrepreneurship and the sustainable development pillars in the short and long term.

Finally, the results of the regression analysis with CO_2 are described in Table VIII.

It could be observed that the level of significance of the variables of the environmental resilience pillar (greening/forestation, urbanization and urban population) is above 5 percent, indicating that none of them influences the CO_2 level according to the proposed one. Therefore, none of the hypotheses (*H3a*: ARB→CO_2; *H3b*: URB→ CO_2; *H3c*: POP.G →CO_2) was confirmed. This enables us to infer that the studied environmental resilience factors are not strong enough to affect significantly the reduction of CO_2 emissions in the cities analyzed.

To conclude, we summarize that of the 11 hypotheses proposed, only four were statistically corroborated. They are: *H1a*: there is a positive relationship between the gross fixed capital per worker and the economic well-being level in smart cities in SP (F.C.→ GNP); *H1b*: there is a positive relationship between innovation (science and technology) and the economic well-being level of smart cities in SP (EMP R.→GNP); *H1c*: there is a positive relationship between human capital and the economic well-being level in smart cities in SP (GRAD→GNP); and *H2c*: there is a negative relationship between the infant mortality rate and the economic well-being level in smart cities in SP (C.M.R→ L.EXP).

The other six hypotheses were not confirmed. *H2a*: it was expected a lower long-term unemployment rate and the social well-being level of the smart cities studied represented by higher life expectancy, and the result was EMP R.→ L. EXP; *H2b*: it was expected a negative relationship between crash fatalities and the social well-being level in smart cities in SP, represented by high life expectancy (A.M.R→ L.EXP); *H2d*: it was expected a negative relationship between the unemployed/uneducated population and the social well-being level in smart cities in SP; *H3a*: it was expected a positive

	Non-standardized coefficient		Standardized coefficient		
	B	Default error	*β*	*t*	Sig.
(Constant)	−5,610,724	4,734,908		−1,185	0.242
F.C	1,029,383	481,282	0.314	2,139	0.037
EMP	−5,999	37,544	−0.025	−0.160	0.874
GRAD	101,124	60,583	0.285	1,669	0.101
EMP R	−20,085	35,307	−0.087	−0.569	0.572
A.M.R	7,920	77,322	0.019	0.102	0.919
C.M.R	235,414	163,390	0.194	1,441	0.156
R.W.E.E.B	32,095	69,468	0.066	0.462	0.646
ARB	−19,757	25,853	−0.134	−0.764	0.448
URB	−8,486	14,229	−0.085	−0.596	0.554
POP.G	0.116	0.099	0.191	1,175	0.246
ANOVA					
	Sum of squares	df	Medium square	*Z*	Sig.
Regression	49,648,342,832	10	4,964,834,283	1,398	0.208[a]
Residue	181,087,645,633	51	3,550,738,150		
Total	230,735,988,465	61			
Model summary					
R	R^2	R^2 adjusted	Standard estimate error	Durbin–Watson	
0.464	0.215	0.061	1,884.34	2,130	

Note: [a]Significance at 1 percent level
Source: Search data (2019)

Table VIII.
Regression with CO_2

relationship between fixed capital per worker and the environmental well-being in smart cities in SP (the higher the population's remuneration, the less CO_2 emission was expected) (ARB $\rightarrow CO_2$); *H3b*: it was expected a negative relationship between artificial infrastructure and the environmental well-being level in smart cities in SP represented by CO_2 emission, and the result was URB $\rightarrow CO_2$; and *H3c*: it was expected a negative relationship between the population growth rate and the environmental well-being level in smart cities in SP (the higher the population rate, the lower the environmental well-being), and the result was POP.G. $\rightarrow CO_2$.

In this regard, the results are partially aligned with those found by Rizzi *et al.* (2018), who found a positive relationship between the territorial results and the regional resilience drivers. So, the economic drivers such as innovation, investment and human capital help explain the economic well-being level measured by GNP per capita, considered as variables of social well-being, which are related with social resilience drivers such as low mortality rate, unemployment rate or social difficulties, as well as the environmental resilience drivers, such as the high biodiversity level and low level of artificial areas explain the good environmental result, summarized in the low level of CO_2 emissions.

5. Conclusion

Resilience thinking promotes the understanding of the evolution of socioeconomic and ecological systems, which describe the urban development from a multidimensional point of view. This study thus consisted in analyzing the urban resilience capacity in relation to economic, social and environmental well-being in smart cities in the state of São Paulo.

Analyzing the pillars of urban resilience separately, it is necessary that the public authorities and other engaged entities from other cities, not only smart cities, have a strategy developed with a high degree of commitment with policies for an effective sustainable development, as well as more awareness of risks and urban disasters, aiming to promote and enhance the well-being and safety of the population within the broad context of urban dynamics. When speaking of natural threats, one should always remind that they should be associated with the main concerns of public administrators, since they affect all cities as a result of disorderly growth, rapid urbanization and environment degradation.

This study contributes to diverse areas, namely, administration, public administration, urban planning, public management, urban sustainability, managerial accounting. Thus, an analysis of urban resilience capacity in how cities are designed, planned and managed is important to determine the results of its influences on sustainable development in different levels of economic, social and environmental well-being; and understand how cities are related with sustainable development mechanisms with the purpose of effectively contributing to environment preservation and the quality of life of the residents, which is the key to foster sustainable development policies.

In addition to the insights and implications provided by this research, some important limitations must be considered. The first one is related with how the tripods of resilience dimensions were measured. It should be noted that the SDG use different indicators for the economic, social and environmental well-being, such as poverty, food security, health, well-being, education quality, climate changes, among others, which can be examined in future studies. Second, this study was limited to smart cities in SP listed in the RBCIH and can be extended to other cities in other Brazilian states. Third, this study examined only the relationship and connection of the resilience pillars with the results of sustainable development. However, the process toward a sustainable resilience dimension is complex and can be achieved through various stages. For this reason, some previous studies (Dhahri & Omri, 2018) suggest implementing some necessary conditions to achieve simultaneously the sustainability goals.

In this direction, future studies could extend this research, employing, mediating or moderating models in order to examine the conditions by which the resilience dimension could meet these goals, as well as to examine the roles of innovation, business alliances and partnerships, civil organization and networks in the advancement of the urban resilience dimensions.

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