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O Impacto dos Indicadores Ambientais na Gestão de Resíduos nas Cidades

The Impact of Environmental Indicators on Waste Management in Cities

El Impacto de los Indicadores Ambientales en la Gestión de Residuos en las Ciudades

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RESUMO

Contexto: Este estudo explora o impacto de indicadores ambientais na qualidade do ar, na gestão de resíduos e na qualidade da água nas cidades. O **objetivo** é avaliar como esses indicadores podem subsidiar políticas urbanas sustentáveis voltadas à melhoria do meio ambiente e da saúde pública. **Metodologia**: A pesquisa utiliza uma abordagem quantitativa e descritiva, utilizando questionários para coleta de dados por meio da ferramenta Google Forms, seguida de análise por meio de estatística descritiva e Modelagem de Equações Estruturais por Mínimos Quadrados Parciais. O estudo identifica quatro indicadores ambientais principais e o desenvolvimento de um modelo inicial composto por 74 questões. Este modelo é avaliado quanto à sua confiabilidade, validade discriminante e validade convergente. O Fator de Inflação da Variância (VIF) é utilizado para analisar a colinearidade. O modelo final inclui valores de R^2 e coeficientes de caminho, que apresentam alto poder explicativo. O estudo **contribui** para a literatura ao oferecer um arcabouço teórico sobre cidades sustentáveis. Do ponto de vista acadêmico, apresenta uma metodologia eficiente para a criação de um mapa estratégico e um modelo estatístico que pode ser utilizado por gestores municipais. Na prática, a pesquisa fornece aos formuladores de políticas públicas um modelo validado que pode auxiliar na gestão e no monitoramento de resíduos urbanos, visando à melhoria da qualidade ambiental e à proteção da saúde pública. Os **resultados** sugerem que, embora os indicadores ambientais impactem significativamente certas áreas, um maior refinamento do modelo poderia ajudar a enfrentar melhor os complexos desafios da sustentabilidade urbana.

Palavras-chave: Cidades inteligentes, saudáveis e sustentáveis. Eficiência energética. Gestão de resíduos.

ABSTRACT

Context: This study explores the impact of environmental indicators on air quality, waste management, and water quality in cities. The **objective** is to evaluate how these indicators can support sustainable urban policies aimed at improving the environment and public health. **Methodology**: The research uses a quantitative and descriptive approach, employing questionnaires for data collection via Google Forms, followed by analysis using descriptive statistics and Partial Least Squares Structural Equation Modeling. The study identifies four main environmental indicators and develops an initial model composed of 74 questions. This model is evaluated for its reliability, discriminant validity, and convergent validity. The Variance Inflation Factor (VIF) is used to analyze collinearity. The final model includes R^2 values and path coefficients, which have high explanatory power. The study **contributes** to the literature by offering a theoretical framework on sustainable cities. From an academic point of view, it presents an efficient methodology for creating a strategic map and a statistical model that can be used by municipal managers. In practice, the research provides policymakers with a validated model that can assist in the management and monitoring of urban waste, aiming to improve environmental quality and protect public health. The **results** suggest that, although environmental indicators significantly impact certain areas, further refinement of the model could help to better address the complex challenges of urban sustainability.

Keywords: Smart, healthy, and sustainable cities. Energy efficiency. Waste management.

RESUMEM

Contexto: Este estudio explora el impacto de los indicadores ambientales en la calidad del aire, la gestión de residuos y la calidad del agua en las ciudades. El **objetivo** es evaluar cómo estos indicadores pueden respaldar políticas urbanas sostenibles destinadas a mejorar el medio ambiente y la salud pública. **Metodología**: La investigación utiliza un enfoque cuantitativo y descriptivo, empleando cuestionarios para la recopilación de datos a través de Formularios de Google, seguido de un análisis mediante estadística descriptiva y modelos de ecuaciones estructurales de mínimos cuadrados parciales. El estudio identifica cuatro indicadores ambientales principales y desarrolla un modelo inicial compuesto por 74 preguntas. Este modelo se evalúa por su fiabilidad, validez discriminante y validez convergente. El Factor de Inflación de la Varianza (FIV) se utiliza para analizar la colinealidad. El modelo final incluye valores R^2 y coeficientes de trayectoria, que tienen un alto poder explicativo. El estudio **contribuye** a la literatura al ofrecer un marco teórico sobre ciudades sostenibles. Desde un punto de vista académico, presenta una metodología eficiente para crear un mapa estratégico y un modelo estadístico que puede ser utilizado por los gestores municipales. En la práctica, la investigación proporciona a los responsables políticos un modelo validado que puede ayudar en la gestión y el monitoreo de los residuos urbanos, con el objetivo de mejorar la calidad ambiental y proteger la salud pública. Los **resultados** sugieren que, si bien los indicadores ambientales tienen un impacto significativo en ciertas áreas, un mayor perfeccionamiento del modelo podría ayudar a abordar mejor los complejos desafíos de la sostenibilidad urbana.

Palabras clave: Ciudades inteligentes, saludables y sostenibles. Eficiencia energética. Gestión de residuos.

INTRODUÇÃO

In the context of economic growth and urbanization, cities without efficient waste management negatively impact the environment as a whole. For example, greenhouse effects in cities and urban residents' health issues are constant challenges in addressing sustainable city development (Santamouris M., 2014, Lu, S.R.; Liu Y, 2018). Urban populations have grown rapidly. Rapid urbanization increases pressure on governments to focus on building a healthy environment for the population.

A global example is China. As the largest developing country, China has undergone rapid urbanization and modernization. Its urbanization rate increased from less than 20% in 1978 to 59.58% in 2018. However, environmental pollution has become increasingly prominent, as China is one of the largest CO_2 emitters, and Chinese cities are under pressure to reduce energy consumption and emissions (Zhang, et al, 2019).

Concrete measures for sustainable environmental construction have been proposed by different researchers in various cities, where governments generally encourage sustainable development actions. However, with the rapid growth of urban populations, the urban environment faces unprecedented challenges, such as worsening pollution, water resource shortages, energy matrix issues, and traffic congestion (Joshi S. et al, 2016). Even though measures such as waste separation, bicycles, electric cars, wastewater treatment, and investments in solar or hydropower plants are applied (Zhang J., Li D, 2011; Liang Y.X et al, 2018), many large cities suffer from poor air quality, inadequate waste management, and poor water quality. Thus, the hypotheses of this research are based on the premise that the characteristics of the energy matrix (solar energy and waste-to-energy plants, wind energy level, hydropower in the energy matrix, and renewable energy potential) and the population's environmental awareness (environmental pressure from consumption and choosing environmentally sustainable products and services), both environmental factors, directly and positively affect air quality, noise pollution, waste management, and water quality.

The objective of this paper is to verify the impact of environmental indicators on air quality, waste management, and water quality in a city. Developing integrated management among various subsystems, especially economic, social, and environmental ones, is an essential part of urban sustainability that directly affects the quality of urbanization (Li & Yi, 2020).

Globally, waste management is a significant environmental issue. In 2016, global annual waste generation levels were 2.01 billion tons, with per capita waste generation at 740 grams per day. Due to rapid urbanization and population growth, waste generation is expected to increase by 70% from 2016 levels, reaching 3.4 billion tons by 2050 (Kalyanasundaram et al., 2021). Proper segregation and disposal of generated waste are critical challenges being addressed globally to achieve environmental protection and improve the health and well-being of cities. The importance of waste management has been recognized and incorporated into all Sustainable Development

Goals (SDGs), directly or indirectly. Therefore, progress in waste management is crucial to achieving nearly all SDGs.

LITERATURE REVIEW

The concept of a healthy city comes from the World Health Organization (WHO) glossary on health promotion, which defines a healthy city as one that aims for the continuous improvement of physical and social environments while expanding community resources, thereby enabling the development of individuals' potential (Organization, 1998).

To reduce environmental impact through recycling and emission reduction, while expanding open spaces and promoting sustainable businesses (El Ghorab & Shalaby, 2016), the concept of a smart city was created to make cities more efficient and competitive (Sokolov, Veselitskaya, Carabias, & Yildirim, 2019). Thus, the smart city concept encompasses a process aimed at making cities efficient and eco-friendly, focusing on the quality of government services and the well-being of the population (Chehri & Mouftah, 2019).

To assist in managing and measuring the economic, social, and environmental sustainability of cities, indicators are used. Indicators can highlight problems that need to be addressed and track the progress of various issues relevant to a city, such as air quality, water quality, and waste management. They can be qualitative or quantitative and aim to demonstrate the state of an operation, system, or process (Francischini & Francischini, 2017).

The urbanization process is challenging, as economic activities generate waste and pollutants that degrade the environment (Li & Yi, 2020). Therefore, urban planning and government policies in favor of the environment can serve as tools to assist in the design and monitoring of cities (Ruan, Yan, & Wang, 2020).

A sustainable city is one that takes into account the three dimensions of sustainability (economic, social, and environmental) in its management (Brito, Ferreira, Perez-Gladish, Govindan, & Meidute-Kavaliauskiene, 2019; Li & Yi, 2020). That is, a sustainable city aims for urban prosperity and economic growth while improving resource use and protecting the environment (Ruan, Yan, & Wang, 2020).

Environmental Indicators for Cities

Hák, Moldan, and Dahl (2007) argue that indicator systems for urban sustainability can be developed through social sustainability, represented by people; environmental sustainability, represented by the planet; and economic sustainability, represented by prosperity, forming the sustainability tripod. On the other hand, regarding urban sustainability, there are limitations concerning the use of environmental sustainability indicators in smart city models, such as energy measurement indicators, which focus more on social and economic fields (Tanguay et al., 2010; Berardi, 2013; Robinson & Cole, 2015; Ahvenniemi, 2017; Chang et al., 2018).

This deficiency is reinforced by the European Commission (2012) and the United Nations (2015), which highlight that among the main objectives of smart cities is to minimize CO2 production and energy consumption. Although indicators of sustainable cities do not reveal their actual situation, whether positive or negative, they reflect an immediate aspect of their sustainability by measuring the city's performance (Mori & Yamashita, 2015). According to Ahvenniemi (2017), performance indicators responsible for measuring environmental, economic, and social sustainability practices should also be part of the performance evaluation system in smart cities. Thus, a scenario is generated that contributes to achieving final objectives that go beyond the implementation of smart solutions (Ahvenniemi, 2017).

Furthermore, sustainability, quality of life, and intelligence correspond to attributes of smart cities, such that sustainability is associated with governance and pollution, quality of life involves emotional well-being, while intelligence encompasses the pursuit of improving economic, social, and environmental parameters (Garau & Pavan, 2018). In other words, smart city indicators begin to impact citizens' quality of life as they incorporate energy and environmental indicators (Carli et al., 2015).

However, the process of assessing urban sustainability is supported by numerous models of indicators and tools for measuring and evaluating performance (Moonen & Clark, 2013; Sharifi & Murayama, 2013; Albino et al., 2015; Berardi, 2015; Anthopoulos, Janssen, & Weerakkody, 2016; Science for Environment Policy, 2018). In the context of the 17 Sustainable Development Goals (SDGs), Goal 11 – "Sustainable Cities and Communities," aims to provide inclusion, safety, resilience, and sustainability to cities and urban settlements, supported by urban sustainability indicators (UN-Habitat et al., 2016).

In this sense, indicators for smart and sustainable cities can be grouped into six sets, as published by international standardization bodies (International Telecommunication Union - ITU, 2016a, 2016b, 2016c; European Telecommunications Standards Institute - ETSI, 2017; International Organization for Standardization - ISO, 2018a, 2018b). On the other hand, it is important to emphasize the quality, reliability, and comparability of performance indicators, favored by the systematic use of these data over time for measuring sustainable cities. This fact goes beyond the adopted evaluation model, whose asymmetry contributes to the non-consensual nature of indicators for smart and sustainable cities (Chang et al., 2018).

Mori and Yamashita (2015) reinforce the importance of using appropriate indicators in smart and sustainable cities, given that their mission is to ensure environmental criteria and equity, ensuring maximum socio-economic benefits for the population. To this end, they rely on themes such as people, planet, prosperity, governance, and outreach, composing a sustainability framework (Singh & Ohri, 2020).

Considering that indicators define performance measurement processes for smart cities, efforts are directed towards achieving smarter cities by proposing an evolutionary monitoring approach for a city (Singh & Ohri, 2020).

Air Quality

In perspectives inherent to urban sustainability indicators, one of the main aspects that directly reflects on the physical-spatial dimension of cities is air quality. In this sense, air quality refers both to the qualitative dimension of urban spaces and represents the historical and cultural dynamics adopted in city planning (Al-Thani et al., 2018).

Thus, among the various aspects that influence air quality in urban spaces, elements related to pollution in its various forms stand out as one of the main and growing problems associated with air quality composition in urban areas (Sefair et al., 2019).

In this context, according to Cantuarias-Villessuzanne, Weigel, & Blain (2021), criteria such as methane emissions and PM 2.5 (Particulate Matter) are determinants in understanding a city's air quality. In this regard, Castelli et al. (2017) warn about the national scale of CO2 measurement as evidence of the impacts of climate change, the identification of urban biodiversity, as well as the presence of parks, natural reserves, wetlands, and tree canopies in the municipality. In urban areas, the improvement of quality of life, represented by air quality, should rely on processes for implementing smart technologies, along with the application of standards for air pollution concentration levels (Crippa et al., 2016; Nižetić et al., 2019; Ahad et al., 2020). Concerning cities, Brdulak (2020) emphasizes that improving air quality, resulting from implemented measures, is thus linked to increased pressure on governments and local authorities. Therefore, it is worth noting the potential of studies contributing to air quality assessment as a parameter for sustainable development (Fenger, 1999; Gurjar, Butler, Lawrence, & Lelieveld, 2008; Holman, Harrison, & Querol, 2015; Pascal et al., 2013; Stone, 2008; Vos, Maiheu, Vankerkom, & Janssen, 2013).

In a study conducted by Sha, Kothari, & Doshi (2019), the authors highlight that since 2008, the New York City Department of Health and Mental Hygiene has been monitoring air quality through research data reports for air quality improvement at 15-minute intervals, generated by 8 permanent air monitors and 75 temporary monitoring stations. Thus, it is noted that the increase in the installation of monitoring networks, in partnership with citizen science projects, contributes to the expansion and an even greater trend towards increased awareness of issues related to air quality (Brdulak, 2020). According to Castelli et al. (2017) and Park et al. (2013), the use of sensors for traffic monitoring has represented one of the main focuses of studies involving air quality monitoring and forecasting. This aspect aligns with the severe effects caused by air pollution, which results in approximately 7 million deaths annually, as suggested by the World Health Organization (WHO) report (Park et al., 2013; Castelli et al., 2017). Thus, it becomes evident that air pollution poses numerous environmental challenges within cities (Castelli et al., 2017).

Despite the various obstacles and dynamics that elevate high levels of air pollution in urban spaces, it is necessary for urban public policies to reassess various aspects inherent to the conception that underlies the term "quality of life" in "sustainable cities" (Benites & Simões, 2021).

H1 - The environment positively influences the air quality of cities.

Noiseless

With the advancement of the urbanization process, various issues permeate the structure of urban-environmental spaces, particularly those related to components of urban public policies. Among the main contemporary urban problems, the issue of urban mobility stands out, both due to urban agglomeration and the consequences generated by traffic (Trindade et al., 2017).

In this perspective, as a consequence of the excessive traffic generated by the issue of urban mobility—or the lack thereof—noise pollution emerges as a major problem in the urban context, continuously increasing day by day. Noise is one of the most significant sources of environmental pollution in metropolitan cities. Traffic noise plays an important role in contributing to the ambient noise pollution in cities. Noise pollution is described as an undesirable sound present in the environment that disrupts the quality of life (Mangalekar et al., 2012).

In this sense, among the main forms of traffic that permeate and favor noise pollution, road traffic stands out, promoting a reverse culture in the urban sustainability process, based on the premise that various alternatives for mobility and access to urban spaces could exist (Tobias et al., 2019).

Thus, controlling noise pollution caused by road traffic becomes a significant challenge, especially for environmental engineers. Noise pollution in cities is the primary issue that must be addressed for improvements in existing traffic systems, construction, and the design of new transportation systems. That said, we present the following research hypothesis:

H2 - The environment positively influences the reduction of noise pollution in cities.

Waste Management

As previously reflected upon, regarding pollution in its various dimensions within urban spaces, the management of solid waste, or waste management, becomes a driving element in the discussion of the quality of other elements in urban spaces. When outlining the issues surrounding waste management, it becomes evident that this element leads to diverse alterations in the natural complex of cities, such as the degradation of rivers, Permanent Preservation Areas, water complexes, as well as problems in drainage and water use cycles (Silva Melo et al., 2020; Veról et al., 2020).

In this context, Mingaleva (2020) adds that each country manages waste in the context of green cities in a particular way. This concept involves not only the integrated waste management of a municipality but also energy recovery (Morero et al., 2020), urban solid waste (Shumal et al., 2020), or, according to Lou et al. (2020), relates to the transportation of household waste through optimized planning.

For societies to become sustainable, various perspectives, namely industrial symbiosis, service ecosystems, resource productivity, and functional alignment, must be incorporated into the circularity of resources, as circulating resources are strategically maintained through waste management (Chertow, 2007; Seuring and Müller, 2008; Sarkar, 2013; Batista et al., 2018). Therefore, the pursuit of control or reduction of generated waste is part of the process of improving waste management (Park et al., 2010; Jacobsen et al., 2018). In recent years, waste management practices have been consolidating as a sustainable system, no longer merely conditioned to simple collection and sorting mechanisms (Arena, 2012; Jacobsen et al., 2018). In light of this new panorama, there is a movement towards balancing product/service system projects, material recovery, and energy management, as well as end-of-life management, mediated by this sustainable system (Arena, 2012; Jacobsen et al., 2018).

Moreover, it is also important to highlight that industries, in conjunction with urban space management, have the duty to promote a sustainable culture and to foresee mechanisms for consolidating public policies that directly reflect on the preservation, measurement, and control of the management of generated waste.

H3 - The environment positively influences waste management in cities.

Water Quality

The quality of water undoubtedly establishes a direct connection with other sustainability indicators of urban spaces and the natural environment itself, highlighting both its socio-environmental and humanistic relevance. As an indispensable element for providing natural balance and maintaining animal, human, and plant life within the urban-environmental complex (Vörösmarty et al., 2018).

Moreover, the advancement of urban expansion over the natural environment, driven by urban planning disconnected from socio-environmental perspectives, leads to the degradation of natural spaces and consequently affects water quality (Silva Melo et al., 2020b).

Since the Rio de Janeiro Conference in 1992, urban planning has been accompanied by terminologies that could somehow represent a better way to "carry out" transformations, moving from an "ecological city" to a "sustainable city" and finally to a "smart city." Each of these adjectives represents a vision of transformations: for example, an ecological city is one with more public green areas, a sustainable city pays more attention to preserving physical and chemical parameters (air and water quality, etc.), and a smart city is more focused on implementing efficient technologies (Campeol, 2017).

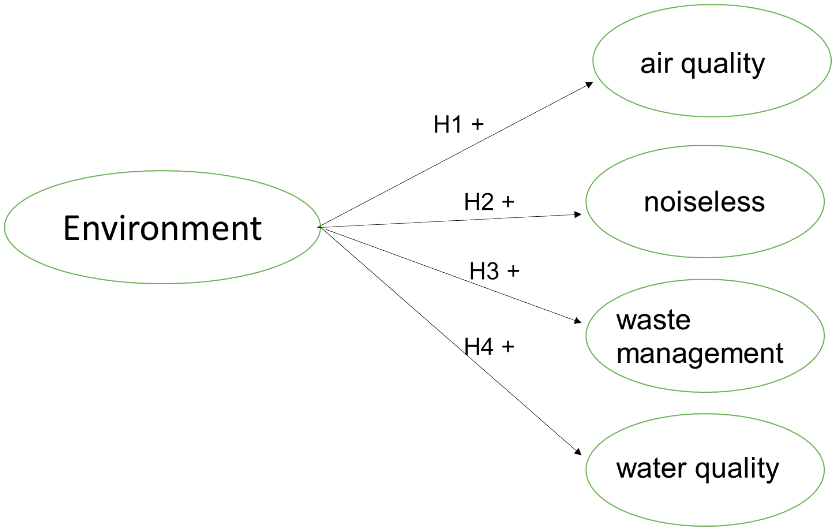
In fact, the interpretations of the transformations mentioned above do not have real meaning, as it is absolutely clear that the city and territory must be transformed considering human, biotic, and abiotic elements; they must adopt an environmental approach. However, the high process of urbanization has exacerbated the degradation of the urban environment, including roadside air quality, solid waste, and water quality (Peter; Yang, 2019).

Thus, it can be seen that the various poles listed earlier, connected through qualitative analysis, find a point of connection under the dynamics of urban planning in cities. Indeed, urban planning can lead to processes that degrade the natural environment, but it can also think, measure, and promote urban sustainability. With that said, we present the following research hypothesis:

H4 - The environment positively influences the quality of water in cities.

Figure 1

Research Framework



METHODOLOGY

The research employs a quantitative, conclusive, descriptive approach, with data collection via survey using Google Forms and analysis through descriptive statistics and Partial Least Squares structural equation modeling. It is quantitative because, according to Saunders, Lewis, and Thornhill (2016), this type of research uses standardized methods for data collection, generating numerical data that can be analyzed through graphs and statistical techniques. For the authors, the quantitative approach allows for the formulation of hypotheses that can be tested (contributing to theory development) or examined in future research. The research is conclusive as it aims to test specific hypotheses and examine relationships. It is descriptive because it seeks to describe the characteristics of a particular phenomenon, aiming to establish relationships between existing variables, such as trust and perceived influence.

Data were collected via survey. To develop the data collection instrument, literature was initially searched for models addressing the research topic that had already been empirically tested. The dimensions outlined in this study were identified, translated, analyzed, and adapted from existing models in the literature, aiming for compatibility with the theme and context of the current research. Thus, the first version of the instrument presented 74 questions regarding the four dimensions.

Subsequently, the initial instrument underwent a pre-test. In the first instance, a group of experts (composed of researchers and professionals in the field of sustainability) reviewed the initial questionnaire and provided feedback on the instrument's ease of understanding, consistency, and the adequacy of the sequence of items, which led to some specific modifications.

Table 1 presents the analyzed dimensions, their descriptions, and the main reference for each dimension.

Table 1

Dimensions of the framework, description, and main reference.

Dimension	Indicators
Waste	Solid, waste, emissions. Total, emissions, of, major, pollutants. Proportion, of, treated, consumption, waste. Rate, of, treatment, of, household, waste.
Water	Access, to, potable, water. Amount, of, treated, wastewater. Presence, of, equipment, for, rainwater, harvesting. Amount, of, wastewater, discharged, by, the, industrial, sector. Source, of, renewable, water. Quality, of, wastewater, treatment, service. Water, reuse, (recycled). Drainage, systems, sewage, and, water. Treatment, of, sewage, and, waste.
Noise	Road, traffic, noise. Level, of, air, noise, in, a, city. Affordable, and, low, noise, pollution, transport, available, to, the, population.
Air	Road, investments, to, reduce, congestion. Cost, of, congestion, (time, spent, by, the, population, in, congestion). Access, to, bike, lanes, in, the, city. Daily, levels, of, suspended, particles. Air, quality.
Environment	Opting, for, environmentally, sustainable, purchases, and, services. Solar, energy, and, energy, from, waste, plants. Level, of, wind, energy. Amount, of, hydropower, in, the, energy, matrix. Potential, for, renewable, energy, and, passivity. Pressure, of, an, individual's, or, population's, consumption, on, the, environment.

Fonte: elaborado pelo autor (2020).

Data collection took place between June 27 and August 18, 2020, conducted online using the Google Forms tool, with promotion on social media and email distribution. In the data analysis, the completion and validation of the received questionnaires were initially verified. A total of 95 questionnaires were collected and validated. Although the sampling was non-probabilistic, it can be considered a homogeneous group with at least one common characteristic: residents of Florianópolis, as recommended by Flynn et al. (1990) and Hourneaux Jr., Gabriel, and Gallardo-Vázquez (2018).

Subsequently, the collected data were entered into Excel spreadsheets and analyzed using descriptive statistics and the partial least squares structural equation modeling technique, with the support of SmartPLS software, version 3.

PRESENTATION AND ANALYSIS OF RESULTS

PLS Analysis (*Partial Least Squares*)

In this subsection, the analysis of Partial Least Squares (PLS) will be conducted in two stages: assessment of the measurement model and analysis of the structural model, both of which are detailed in the following sections.

Model Assessment – Validity and Reliability

The model assessment began with its discriminant validity, convergent validity, and reliability as recommended by Hair Junior et al. (2017).

We started by analyzing the convergent validity and discriminant validity of the observed variables. Initially, the cross-factor loadings were evaluated according to Chin's (1998) criterion, which proved to be adequate, as shown in Table 2:

Table 2

Values of the Cross Loadings of the Observed Variables on the Latent Variables

Variable	Air	Noise	Environment	Waste	Water
Air Pollution 1	0.742	0.400	0.536	0.480	0.518
Air Pollution 2	0.880	0.489	0.695	0.551	0.553
Air Pollution 5	0.820	0.546	0.672	0.635	0.776
Noise 1	0.694	0.828	0.457	0.422	0.428
Noise 2	0.720	0.858	0.628	0.634	0.656
Noise 3	0.610	0.831	0.628	0.634	0.656
Environment 1	0.487	0.456	0.842	0.600	0.462
Environment 2	0.596	0.514	0.905	0.614	0.634
Environment 3	0.505	0.543	0.733	0.506	0.477
Environment 5	0.623	0.586	0.879	0.660	0.554
Environment 6	0.543	0.559	0.764	0.667	0.562
Waste 1	0.536	0.524	0.493	0.849	0.565
Waste 2	0.501	0.520	0.493	0.849	0.531
Waste 3	0.636	0.723	0.484	0.827	0.592
Waste 4	0.778	0.649	0.59	0.808	0.806
Water 1	0.772	0.555	0.574	0.664	0.883
Water 2	0.735	0.579	0.529	0.690	0.922
Water 3	0.770	0.652	0.594	0.709	0.924
Water 4	0.649	0.546	0.550	0.718	0.846
Water 5	0.650	0.519	0.495	0.588	0.853
Water 6	0.782	0.605	0.586	0.703	0.940
Water 7	0.765	0.633	0.575	0.711	0.879
Water 8	0.704	0.495	0.579	0.573	0.866

Source: Prepared by the author, based on research data (SMARTPLS3®, 2020).

Based on the analysis of Table X, it can be observed that the factor loadings of the observed variables are greater than 0.5, satisfying the criterion for convergent validity. The factor loadings of the observed variables within their respective latent variable are higher compared to the other latent variables. Thus, the discriminant validity of the observed variables has been established.

After analyzing the observed variables, we move on to the analysis of the latent variables. The discriminant validity of the latent variables indicates whether they are independent from each other (HAIR JUNIOR et al., 2017). For this analysis, we will use the Fornell-Larcker criterion, which states that the square roots of the AVE (Average Variance Extracted) must be greater than the correlations among the other latent variables (FORNELL; LARCKER, 1981). Table 3 presents the values of the correlations between latent variables and the square roots of the AVE values on the main diagonal (highlighted).

Table 3

Values of correlations between latent variables (LV) and square roots of AVE values on the main diagonal (highlighted)

	Air	Noise	Environment	Waste	Water
Air Pollution	0.816				
Noise Pollution	0.784	0.839			
Environment	0.593	0.645	0.827		
Waste	0.688	0.662	0.741	0.834	
Water Pollution	0.762	0.627	0.651	0.755	0.890

Source: Prepared by the author, based on research data (SMARTPLS3®, 2019).

Based on the analysis of Table X, it can be observed that all correlation values between the latent variables are lower than the square roots of their AVEs; therefore, the Fornell-Larcker criterion has been met.

Finally, the convergent validity of the latent variables was evaluated through the AVEs, as well as the internal consistency of the model, using Cronbach's Alpha and composite reliability. Table 4 demonstrates these values.

Table 4

Values Related to the Internal Consistency of the Model and AVE

Dimension	Alfa de Cronbach	Composite Reliability	AVE
Air Pollution	0.749	0.856	0.666
Noise Pollution	0.793	0.877	0.704
Environment	0.883	0.915	0.685
Waste	0.856	0.901	0.695
Water Pollution	0.962	0.968	0.792

Source: Elaborated by the author, based on research data (SMARTPLS3®, 2020).

The values of the AVE greater than 0.6 indicate that the convergent validity of the latent variables has been met. It is also noted in Table X that the Cronbach's alpha for the constructs is greater than 0.70. Furthermore, the reliability criterion was considered met, as the composite reliability indices exceeded 0.8 (HAIR JUNIOR et al., 2017).

In order to meet the statistical prerequisites for the validity of the variables, indicators were excluded from the model so that it retains both convergent and discriminant validity of the observed and latent variables, as well as internal consistency.

Therefore, following the validation of the measurement model based on the criteria described above, the next subsection will focus on the analysis of the structural model.

Evaluation of the Structural Model

The first evaluation conducted consisted of analyzing collinearity using the Variance Inflation Factor (VIF). According to Hair Junior et al. (2017), non-compliance with this assumption can render inferences based on the model erroneous or unreliable. It is emphasized that, in the context of structural equation modeling using the PLS-SEM method, a VIF value equal to or greater than five indicates a potential collinearity problem. However, according to Hair Junior et al. (2017), one should consider removing one of the corresponding indicators if the level of collinearity is very high, as indicated by a VIF value equal to or greater than ten. Table 5 demonstrates these values:

Table 5

Values related to the Variance Inflation Factor (VIF).

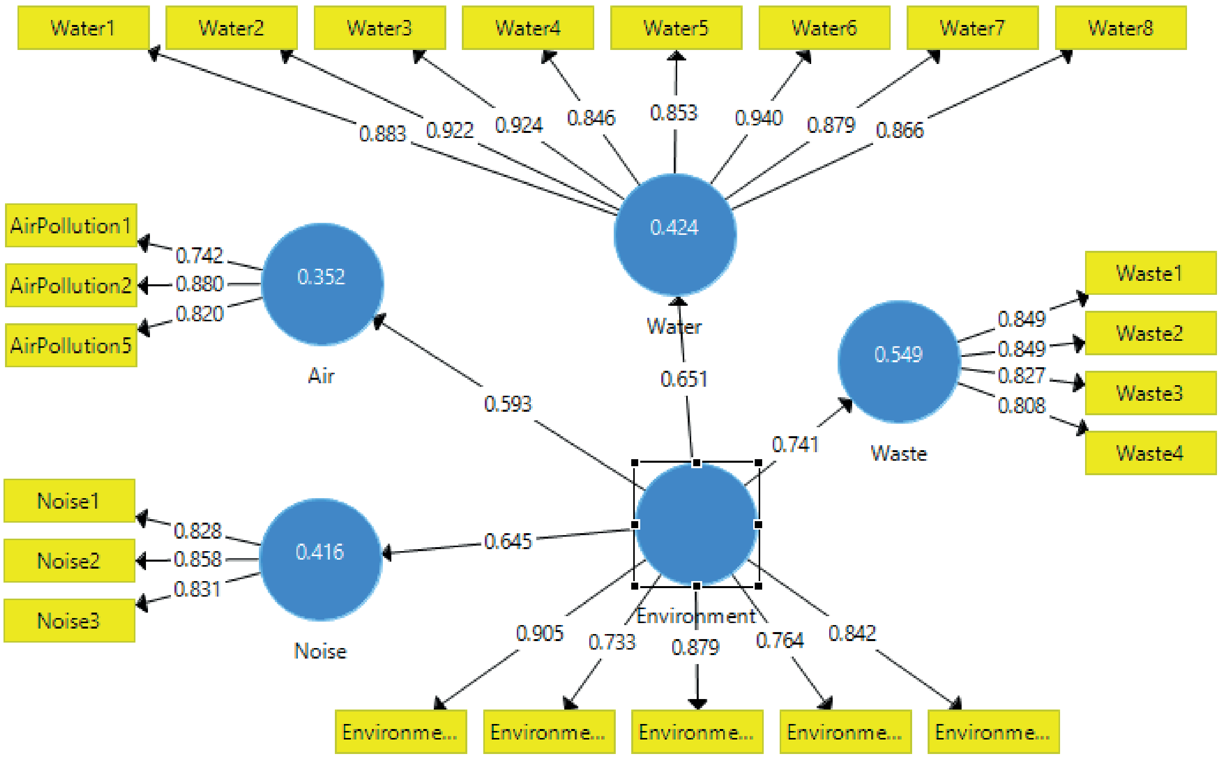
Air Pollution 1	1.512	**Environment 3**	1.728	**Water 2**	5.429
Air Pollution 2	1.986	**Environment 5**	3.106	**Water 3**	5.898
Air Pollution 5	1.488	**Environment 6**	1.635	**Water 4**	3.209
Noise 1	1.778	**Waste 1**	6.530	**Water 5**	4.047
Noise 2	1.587	**Waste 2**	6.528	**Water 6**	6.759
Noise 3	1.695	**Waste 3**	1.875	**Water 7**	3.798
Environment 1	2.660	**Waste 4**	1.855	**Water 8**	3.999
Environment 2	0.386	**Water 1**	4.912		

Source: Elaborated by the author, based on research data (SMARTPLS3®, 2020).

Since all the values are below seven, it was decided to keep all the variables. Subsequently, the Pearson's coefficient of determination (R^2) was evaluated. The R^2 serves to assess the portion of the variance of the dependent variables that is explained by the structural model. Figure 2 presents the structure of the measurement model, with the values of R^2 and path coefficients.

Figure 2

Proposed model, R^2, and path coefficients.



Source: SmartPLS3® (2020).

It is observed that the dependent variables have an R^2 greater than 0.26, indicating a high degree of explanation, according to the classifications of Cohen (1988) and Hair Junior et al. (2017). The model explained a substantial part of the variation in noise pollution (41.6%), air pollution (35.2%), water pollution (42.4%), and waste generation (54.9%).

To test the significance of the indicated relationships, the bootstrapping technique was used, which is a resampling method employed to assess the significance of measurement models and the structural model. Thus, a bootstrapping resampling procedure with 5,000 bootstrap samples per group was conducted and analyzed. As shown in Table 6, all hypotheses are above the reference value (1.96) in the T Statistics, supporting the hypotheses at a p-value of 1%. In this case, the null hypotheses (H0) were rejected, and it can be said that the correlations and regression coefficients are significant, providing support for this part of the proposed model.

Table 6

Hypothesis Testing

Hypothesis		T Statistics	P Values	Results
H1	Environment ➡ Air	4.031	0.000	Suportada
H2	Environment ➡ Noise	6.207	0.000	Suportada
H3	Environment ➡ Waste	8.943	0.000	Suportada
H4	Environment ➡ Water	4.461	0.000	Suportada

Source: Prepared by the author (2019).

Discussion of the results in light of theory.

Air quality is one of the elements that contribute to the quality of life in cities, and it is essential to highlight other factors such as noise pollution, water quality, and the management of solid waste. These aspects are also part of the discussions surrounding sustainability indicators.

The primary source of noise pollution in urban areas is vehicular traffic, where urban traffic noise poses a serious health risk to humans, not only compromising hearing but also affecting physiological states by increasing breathing rate and pulse (Savale, 2014; Fiedler & Zannin, 2015). Traffic constitutes a significant portion of the urban environment, contributing approximately 55% of total urban noise (Vijay et al., 2014; Laxmi et al., 2019).

Moreover, the adaptation process to climate change, as well as the protection and conservation of urban ecosystems, are among the challenges faced by waste management. This is a crucial element inherent to the concepts of smart and green cities and intelligent security systems (Mingaleva et al., 2020). Measuring the recycling performance of waste management systems (Park et al., 2010; Brilhante & Klaas, 2018; Jacobsen et al., 2018) is essential in the context of green city development investigations (Brilhante & Klaas, 2018).

Additionally, water quality, as a sustainability indicator, permeates various contexts, including both direct and indirect use, and is also a socio-environmental asset of the spaces. Water quality is not only subject to ecological maintenance but also integrates areas designated for permanent protection in municipalities (Fiore et al., 2019).

CONSIDERATIONS

The model assessment began with the analysis of convergent and discriminant validity. The observed variables demonstrated adequate convergent validity, with factor loadings greater than 0.5, indicating a strong correlation with their respective latent variables. Discriminant validity was confirmed by the Fornell-Larcker criterion, which showed that the square roots of the Average Variance Extracted (AVE) were greater than the correlations among the latent variables, ensuring that they are distinct.

Additionally, the internal consistency of the model was validated through Cronbach's Alpha and composite reliability, both showing values above 0.70 and 0.80, respectively, suggesting that the constructs are reliable. To maintain the validity of the model, some indicators were excluded, ensuring convergent and discriminant validity, as well as internal consistency. With the validation of the measurement model completed.

The model assessment used the Variance Inflation Factor (VIF) to check for collinearity among the variables, with all values falling below seven, indicating the absence of significant collinearity issues. The coefficient of determination (R^2) for the dependent variables was greater than 0.26, demonstrating a high explanatory capacity for variations in phenomena such as noise pollution (41.6%), air pollution (35.2%), water pollution (42.4%), and waste generation (54.9%). These results suggest that the model is effective in predicting and understanding the analyzed relationships.

To test the significance of the relationships among the variables, the bootstrapping technique was applied, resulting in T values greater than 1.96, allowing for the rejection of the null hypotheses (H0). This confirms that the correlations and regression coefficients are statistically significant, providing solid support for the proposed model. Overall, the analysis reveals that the model is robust and valid, capable of offering relevant insights into the relationship between pollution and urban factors.

Suggestions for future research include exploring complementary indicators of urban sustainability, conducting longitudinal analyses to understand the evolution of pollution variables, and performing comparative studies between cities to identify effective management practices. Additionally, investigating community perceptions of pollution and sustainability and applying advanced modeling to simulate urban dynamics can provide valuable insights for the development of public policies.

REFERÊNCIAS

Ahad, M. A., Paiva, S., Tripathi, G., & Feroz, N. (2020). Enabling technologies and sustainable smart cities. Sustainable cities and society, 61, 102301.

Ahvenniemi, H., Huovila, A., Pinto-Seppä, I., & Airaksinen, M. (2017). What are the differences between sustainable and smart cities?. Cities, 60, 234-245.

Albino, V., Berardi, U., & Dangelico, R. M. (2015). Smart cities: Definitions, dimensions, performance, and initiatives. Journal of urban technology, 22(1), 3-21.

Al-Thani, H., Koç, M., & Isaifan, R. J. (2018). A review on the direct effect of particulate atmospheric pollution on materials and its mitigation for sustainable cities and societies. In Environmental Science and Pollution Research (Vol. 25, Issue 28, pp. 27839–27857).

Anthopoulos, L., Janssen, M., & Weerakkody, V. (2019). A Unified Smart City Model (USCM) for smart city conceptualization and benchmarking. Smart cities and smart spaces: Concepts, methodologies, tools, and applications, 247-264.

Arena, U. (2012). Process and technological aspects of municipal solid waste gasification. A review. Waste management, 32(4), 625-639.

Batista, L., Bourlakis, M., Liu, Y., Smart, P., & Sohal, A. (2018). Supply chain operations for a circular economy. Production Planning & Control, 29(6), 419-424.

Benites, A. J., & Simões, A. F. (2021). Assessing the urban sustainable development strategy: An application of a smart city services sustainability taxonomy. Ecological Indicators, 127. https://doi.org/10.1016/j.ecolind.2021.107734 .

Berardi, U. (2013). Sustainability assessment of urban communities through rating systems. Environment, development and sustainability, 15(6), 1573-1591.

Brdulak, A. (2020). Characteristics of Narrowband IoT (NB-IoT) technology that supports smart city management, based on the chosen use cases from the environment area. Journal of Decision Systems, 1-8.

Brilhante, O., & Klaas, J. (2018). Green city concept and a method to measure green city performance over time applied to fifty cities globally: Influence of GDP, population size and energy efficiency. Sustainability, 10(6), 2031.

Brito, V. T. F., Ferreira, F. A. F., Perez-Gladish, B., Govindan, K., & Meidute-Kavaliauskiene, I. (2019). Developing a green city assessment system using cognitive maps and the Choquet Integral. Journal of Cleaner Production, 218, 486-497. doi: https://doi.org/10.1016/j.jclepro.2019.01.060

Campeol, Giovanni; Carollo, Sandra; Masotto, Nicola. Development Theories and Infrastructural Planning: the Belluno Province. Book Green Energy and Technology, autors Bisello, A; Vettorato, D; Stephens, R; Elisei, P, p. 299-315, DOI: https://doi.org/10.1007/978- , 2017.

Cantuarias-Villessuzanne, C., Weigel, R., & Blain, J. (2021). Clustering of European Smart Cities to Understand the Cities' Sustainability Strategies. Sustainability, 13(2), 513.

Carli, ., Albino, V., Dotoli, M., Mummolo, G., & Savino, M. (2015, July). A dashboard and decision support tool for the energy governance of smart cities. In 2015 IEEE Workshop on Environmental, Energy, and Structural Monitoring Systems (EESMS) Proceedings (pp. 23-28). IEEE.

Castelli, M.; Gonçalves, I.; Trujillo, L.; Popoviˇc, A. An Evolutionary System for Ozone Concentration Forecasting. Inf. Syst. Front. 2017, 19, 1123–1132.

Chang, D. L., Sabatini-Marques, J., Da Costa, E. M., Selig, P. M., & Yigitcanlar, T. (2018). Knowledge-based, smart and sustainable cities: A provocation for a conceptual framework. Journal of Open Innovation: Technology, Market, and Complexity, 4(1), 5.

Chehri, A., & Mouftah, H. T. (2019). Autonomous vehicles in the sustainable cities, the beginning of a green adventure. Sustainable Cities and Society, 51, 101751. doi: https://doi.org/10.1016/j.scs.2019.101751

Chertow, M. R. (2007). "Uncovering" industrial symbiosis. Journal of industrial Ecology, 11(1), 11-30.

Chin, W. W. The partial least squares approach for structural equation modeling. *In*: Marcoulides, G.A. Modern methods for business research. London: Lawrence Erlbaum Associates, 1998. P. 295-336.

Cohen, J. Statistical Power Analysis for the Behavioral Sciences. 2 ed. Nova York: Psychology Press, 1988.

Crippa, M., Janssens-Maenhout, G., Dentener, F., Guizzardi, D., Sindelarova, K., Muntean, M., ... Granier, C. (2016). Forty years of improvements in European air quality: Regional policy-industry interactions with global impacts. Atmospheric Chemistry and Physics, 16, 3825–3841.

El Ghorab, H. K., & Shalaby, H. A. (2016). Eco and Green cities as new approaches for planning and developing cities in Egypt. Alexandria Engineering Journal, 55(1), 495-503. doi: https://doi.org/10.1016/j.aej.2015.12.018

European Commission (2012). Communication from the commission. Smart cities and communities – European innovation partnership. Brussels. http://ec.europa.eu/energy/ technology/initiatives/doc/2012_4701_smart_cities_en.pdf (accessed 10.2.2016)

European Telecommunications Standards Institute (2017). ETSI TS 103 463 key performance indicators for sustainable digital multiservice cities. Technical specification V1.1.1 (2017-07). http://www.etsi.org/deliver/etsi_ts/103400_103499/103463/01.01.01_60/ts_103463v010101p.pdf , Accessed date: 15 June 2018.

Fenger, J. (1999). Urban air quality. Atmospheric Environment, 33(29), 4877–4900.

Fiore, N. V., Ferreira, C. C., Dzedzej, M., & Massi, K. G. (2019). Monitoring of a seedling planting restoration in a permanent preservation area of the southeast atlantic forest biome, Brazil. Forests, 10(9), 1–12. https://doi.org/10.3390/f10090768

Flynn, B.B., Kakibara, S.S., Schroeder, R.G., Bates, K.A. and Flynn, E.J. (1990), "Empirical research methods in operations management", Journal of Operations Management, Vol. 9 No. 2, pp. 250-284

Fornell, C.; Larcker, D.F. Evaluating structural equation models with unobservable variables and measurement error. Journal of Marketing Research, v.18, n. 1, p. 39-50, 1981.

Francischini, A. S. N., & Francischini, P. G. (2017). Indicadores de desempenho.

Garau, C., & Pavan, V. M. (2018). Evaluating urban quality: Indicators and assessment tools for smart sustainable cities. Sustainability, 10(3), 575.

Giles-Corti, B., Lowe, M., & Arundel, J. (2019). Achieving the SDGs: Evaluating indicators to be used to benchmark and monitor progress towards creating healthy and sustainable cities. Health Policy. doi: https://doi.org/10.1016/j.healthpol.2019.03.001

Gurjar, B. R., Butler, T. M., Lawrence, M. G., & Lelieveld, J. (2008). Evaluation of emissions and air quality in megacities. Atmospheric Environment, 42(7), 1593–1606.

Hair Junior, J.F. *et al.* A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM). 2. Ed. Los Angeles: SAGE, 2017.

Hák, T., Moldan, B., & Dahl, A. L. (Eds.). (2012). Sustainability indicators: a scientific assessment (Vol. 67). Island Press.

Holman, C., Harrison, R., & Querol, X. (2015). Review of the efficacy of low emission zones to improve urban air quality in European cities. Atmospheric Environment, 111, 161–169.

Hourneaux Jr, Gabriel, Gallardo-Vázquez (2018) Triple bottom line and sustainable performance measurement in industrial companies. Revista de Gestão. 25 (4)

International Standardization Organization (2018a). ISO 37120:2018 Sustainable cities and communities — Indicators for city services and quality of life (2nd ed.). (2018-07).

International Standardization Organization (2018b). ISO/DIS 37122 Sustainable cities and communities – Indicators for smart cities. (Published 2018-06-06).

International Telecommunication Union (2016a). Recommendation ITU-T Y.4901/L.1601key performance indicators related to the use of information and communication technology in smart sustainable cities.

International Telecommunication Union (2016b). Recommendation ITU-T Y.4902/L.1602 key performance indicators related to the sustainability impacts of information and communication technology in smart sustainable cities.

International Telecommunication Union (2016c). Recommendation ITU-T Y.4903/L.1603 key performance indicators for smart sustainable cities to assess the achievement of Sustainable Development Goals.

Jacobsen, R., Willeghems, G., Gellynck, X., & Buysse, J. (2018). Increasing the quantity of separated post-consumer plastics for reducing combustible household waste: The case of rigid plastics in Flanders. Waste management, 78, 708-716.

Jing, Z., & Wang, J. (2020). Sustainable development evaluation of the society–economy–environment in a resource-based city of China:A complex network approach. Journal of Cleaner Production, 121510. doi: https://doi.org/10.1016/j.jclepro.2020.121510

Joshi S., Saxena S., Godbole T., Shreya Developing Smart Cities: An Integrated Framework. Procedia Comput. Sci. 2016

Laxmi, Vijaya; Dey, Jaydip; Kalawapudi, Komal; Kumar, Rakesh. An innovative approach of urban noise monitoring using cycle in Nagpur, India. Environmental Science and Pollution Research. December 2019. DOI: https://doi.org/10.1007/s11356-019-06817-0

Li, W., & Yi, P. (2020). Assessment of city sustainability—Coupling coordinated development among economy, society and environment. Journal of Cleaner Production, 256, 120453. doi: https://doi.org/10.1016/j.jclepro.2020.120453

Liang Y.X., Cheng X.W., Zhu H., Shutes B., Yan B.X., Zhou Q.W., Yu X.F. Historical evaluation of mariculture in China during past 40 years and its impacts on eco-environment. Chin. Geogr. Sci. 2018

Lou, C. X., Shuai, J., Luo, L., & Li, H. (2020). Optimal transportation planning of classified domestic garbage based on map distance. Journal of environmental management, 254, 109781.

Lu S.R., Liu Y. Evaluation system for the sustainable development of urban transportation and ecological environment based on SVM. J. Intell. Fuzzy Syst. 2018.

Madhanraj Kalyanasundaram; Yogesh Sabde; Kristi Sidney Annerstedt; Surya Singh; Krushna Chandra Sahoo; Vivek Parashar; Manju Purohit; Ashish Pathak; Cecilia Stålsby Lundborg; Kamran Rousta; Kim Bolton; Salla Atkins; Vishal Diwan. Effects of improved information and volunteer support on segregation of solid waste at the household level in urban settings in Madhya Pradesh, India (I-MISS): protocol of a cluster randomized controlled trial. BMC Public Health (2021) https://doi.org/10.1186/s12889-021-10693-0

Mangalekar, S. B., Jadhav, A. S., and Raut P. D. (2012): Study of noise pollution in Kolhapur city, Maharashtra, India. Vol. 2 issue 1, 65-69.

Meerow, S. (2020). The politics of multifunctional green infrastructure planning in New York City. Cities, 100, 102621. doi: https://doi.org/10.1016/j.cities.2020.102621

Mingaleva, Z., Vukovic, N., Volkova, I., & Salimova, T. (2020). Waste management in green and smart cities: A case study of Russia. Sustainability, 12(1), 94.

Moonen, T., Clark, G., & Feenan, R. (2013). The business of cities 2013: What do 150 city indexes and benchmarking studies tell us about the urban world in 2013. Jones Lang LaSalle.

Morero, B., Montagna, A. F., Campanella, E. A., & Cafaro, D. C. (2020). Optimal process design for integrated municipal waste management with energy recovery in Argentina. Renewable Energy, 146, 2626-2636.

Mori, K., & Yamashita, T. (2015). Methodological framework of sustainability assessment in City Sustainability Index (CSI): A concept of constraint and aximization indicators. Habitat International, 45, 10-14.

Nižetić, S., Djilali, N., Papadopoulos, A., & Rodrigues, J. J. (2019). Smart technologies for promotion of energy efficiency, utilization of sustainable resources and waste management. Journal of cleaner production, 231, 565-591.

Organization, W. H. (1998). Glossary WHO Health Promotion Glossary.

Park, J., Lim, S. B., Hong, K. H., Pyeon, M. W., & Lin, J. Y. (2013). An application of emission monitoring system based on real-time traffic monitoring. International Journal of Information Processing and Management, 4(1), 51–57.

Park, J., Sarkis, J., & Wu, Z. (2010). Creating integrated business and environmental value within the context of China's circular economy and ecological modernization. Journal of Cleaner Production, 18(15), 1494-1501.

Pascal, M., Corso, M., Chanel, O., Declercq, C., Badaloni, C., Cesaroni, G., ... Aphekom group. (2013). Assessing the public health impacts of urban air pollution in 25. European cities: Results of the Aphekom project. The Science of the Total Environment, 449, 390–400.

Petern; Linda Lazaro; Yang, Yuzhen. Urban planning historical review of master plans and the way towards a sustainable city: Dar es Salaam, Tanzania, Frontiers of Architectura Research Volume 8, Issue 3, September 2019, Pages 359-377

Robinson, J., & Cole, R. J. (2015). Theoretical underpinnings of regenerative sustainability. Building Research & Information, 43(2), 133-143.

Ruan, F., Yan, L., & Wang, D. (2020). The complexity for the resource-based cities in China on creating sustainable development. Cities, 97, 102571. doi: https://doi.org/10.1016/j.cities.2019.102571

Santamouris M. On the energy impact of urban heat island and global warming on buildings. Energy Build. 2014.

Sarkar, A. N. (2013). Promoting eco-innovations to leverage sustainable development of eco-industry and green growth. European Journal of Sustainable Development, 2(1), 171-171.

Saunders, M.; Lewis, P.; Thornhill, A. Research methods for business students. 7 ed. Pearson Education, 2016.

Science for Environment Policy (2018). Indicators for sustainable cities. In-depth report 12. Produced for the European Commission DG Environment by the Science Communication Unit, UWE, Bristol.

Seuring, S., & Müller, M. (2008). From a literature review to a conceptual framework for sustainable supply chain management. Journal of cleaner production, 16(15), 1699-1710.

Sefair, J. A., Espinosa, M., Behrentz, E., & Medaglia, A. L. (2019). Optimization model for urban air quality policy design: A case study in Latin America. Computers, Environment and Urban Systems, 78, 101385. https://doi.org/10.1016/J.COMPENVURBSYS.2019.101385

Shah, J., Kothari, J., & Doshi, N. (2019). A survey of smart city infrastructure via case study on New York. Procedia Computer Science, 160, 702-705.

Sharifi, A., & Murayama, A. (2013). A critical review of seven selected neighborhood sustainability assessment tools. Environmental impact assessment review, 38, 73-87.

Shumal, M., Jahromi, A. R. T., Ferdowsi, A., Dehkordi, S. M. M. N., Moloudian, A., & Dehnavi, A. (2020). Comprehensive analysis of municipal solid waste rejected fractions as a source of Refused Derived Fuel in developing countries (case study of Isfahan-Iran): Environmental Impact and sustainable development. Renewable Energy, 146, 404-413.

Silva Melo, T., Mota, J. V. L., e Silveira, N. D. B., de Andrade, A. R. S., Peres, M. C. L., de Oliveira, M. L. T., & Delabie, J. H. C. (2020a). Combining ecological knowledge with brazilian urban zoning planning. Urbe, 12. https://doi.org/10.1590/2175-3369.012.E20190135

Silva Melo, T., Mota, J. V. L., e Silveira, N. D. B., de Andrade, A. R. S., Peres, M. C. L., de Oliveira, M. L. T., & Delabie, J. H. C. (2020b). Combining ecological knowledge with brazilian urban zoning planning. Urbe, 12, 2021. https://doi.org/10.1590/2175-3369.012.E20190135

Singh, P. K., & Ohri, A. (2020). Selecting Environmental Indicators for Sustainable Smart Cities Mission in India. Nature Environment and Pollution Technology, 19(1), 201-210.

Sokolov, A., Veselitskaya, N., Carabias, V., & Yildirim, O. (2019). Scenario-based identification of key factors for smart cities development policies. Technological Forecasting and Social Change, 148, 119729. doi: https://doi.org/10.1016/j.techfore.2019.119729

Steiniger, S., Wagemann, E., de la Barrera, F., Molinos-Senante, M., Villegas, R., de la Fuente, H., . . . Barton, J. R. (2020). Localising urban sustainability indicators: The CEDEUS indicator set, and lessons from an expert-driven process. Cities, 101. doi: https://doi.org/10.1016/j.cities.2020.102683

Stone, B., Jr. (2008). Urban sprawl and air quality in large US cities. Journal of Environmental Management, 86(4), 688–698.

Tanguay, G. A., Rajaonson, J., Lefebvre, J. F., & Lanoie, P. (2010). Measuring the sustainability of cities: An analysis of the use of local indicators. Ecological Indicators, 10(2), 407-418.

Tobias, M. S. G., Ramos, R. A. R., & Rodrigues, D. S. (2019). Use of waterway transport integrated to urban transportation systems in Amazonian cities: A vision of sustainable mobility. WIT Transactions on Ecology and the Environment, 238, 615–625. https://doi.org/10.2495/SC190531

Trindade, E. P., Hinnig, M. P. F., da Costa, E. M., Marques, J. S., Bastos, R. C., & Yigitcanlar, T. (2017). Sustainable development of smart cities: A systematic review of the literature. Journal of Open Innovation: Technology, Market, and Complexity, 3(3). https://doi.org/10.1186/s40852-017-0063-2

UN-Habitat, UNESCO, World Health Organisation, UNISDR, UN Women, UNEP, et al. (2016). SDG goal 11 monitoring framework. http://unhabitat.org/sdg-goal-11-monitoring-framework/ , Accessed date: 19 June 2018.

United Nations (2015). Habitat III issue papers, 21 – Smart cities. V. 2.0 (31 May 2015), issued in New York, USA, by UN task team on Habitat III, a task force of UN agencies and programs for the New Urban Agenda, prepared for Habitat III United Nations Conference on Housing and Sustainable Urban Development to take place in Quito, Ecuador, 17–20 October 2016.

Veról, A. P., Lourenço, I. B., Fraga, J. P. R., Battemarco, B. P., Merlo, M. L., de Magalhães, P. C., & Miguez, M. G. (2020). River restoration integrated with sustainable urban water management for resilient cities. Sustainability (Switzerland), 12(11). https://doi.org/10.3390/su12114677

Vijay, Ritesh; Kori, Chandan; Kumar, Manoj; Chakrabarti, Tapan; Gupta, Rajesh. Assessment of Traffic Noise on Highway Passing from Urban Agglomeration. Fluctuation and Noise Letters Vol. 13, No. 04, 1450031 (2014)

Vörösmarty, C. J., Rodríguez Osuna, V., Cak, A. D., Bhaduri, A., Bunn, S. E., Corsi, F., Gastelumendi, J., Green, P., Harrison, I., Lawford, R., Marcotullio, P. J., McClain, M., McDonald, R., McIntyre, P., Palmer, M., Robarts, R. D., Szöllösi-Nagy, A., Tessler, Z., & Uhlenbrook, S. (2018). Ecosystem-based water security and the Sustainable Development Goals (SDGs). *Ecohydrology & Hydrobiology*, *18*(4), 317–333. https://doi.org/10.1016/J.ECOHYD.2018.07.004 .

Vos, P. E., Maiheu, B., Vankerkom, J., & Janssen, S. (2013). Improving local air quality in cities: to tree or not to tree? Environmental Pollution, 183, 113–122.

Zhang J., Li D. Study on water environment restoration and urban water system healthy circulation. Eng. Sci. 2011

Zhang S.F., Hu T.T., Li J.B., Cheng C., Song M.L., Xu B. The effects of energy price, technology, and disaster shocks on China's Energy-Environment-Economy system. J. Clean. Prod. 2019

APENDIX

Variable	Indicator
Air Pollution 1	Road investments to reduce congestion
Air Pollution 2	Price of congestion (Time spent by the population in traffic jams)
Air Pollution 3	Access to cycle paths in the city
Air Pollution 4	Daily levels of suspended particles
Air Pollution 5	Air quality
Noise 1	Road traffic noise
Noise 2	Air noise level in a city
Noise 3	Cheap and low-noise transport available to the population
Environment 1	Choosing environmentally sustainable purchases and services
Environment 2	Solar energy and energy from waste-to-energy plants
Environment 3	Level of wind energy
Environment 4	Amount of hydroelectric energy in the energy matrix
Environment 5	Potential for renewable energy and passivity
Environment 6	Pressure of consumption by a citizen or population on the environment
Waste 1	Solid waste emissions
Waste 2	Total emissions of main pollutants
Waste 3	Proportion of consumer waste treated
Waste 4	Household waste treatment rate
Water 1	Access to drinking water
Water 2	Amount of treated wastewater
Water 3	Presence of equipment for collecting rainwater
Water 4	Amount of wastewater emitted by the industrial sector
Water 5	Source of renewable water
Water 6	Quality of water treatment service Wastewater
Water 7	Reuse of water (recycled)
Water 8	Drainage, sewage and water systems
Water 9	Sewage and waste treatment

NOTAS

Licença de Uso

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