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Article

Sustainability Indicators of ISO 37120 in the Municipality of Hortolândia, São Paulo, Brazil

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Abstract: This study analyzes the performance of the municipality of Hortolândia, São Paulo in light of the core urban sustainability themes defined by ISO 37120—water, wastewater, energy, solid waste, environment, and climate change—identifying advances and limitations in local governance while discussing institutional and public policy implications applicable to other urban contexts. This applied study uses a quantitative-descriptive, exploratory approach based on documentary analysis of strategic plans, technical reports, and official governmental statistics. The data were organized and analyzed in accordance with the ABNT NBR ISO 37120 standard, including the calculation of indicators and comparison with Brazilian regional and national benchmarks. The results indicate high coverage of potable water and a high level of quality compliance, as well as strong performance in wastewater collection and treatment and near universal access to residential electricity, predominantly from renewable sources. In contrast, solid waste management presents weaknesses in recycling and a predominance of landfill disposal. Although air quality is classified as "good", greenhouse gas emissions remain high. The findings indicate that, although the municipality demonstrates significant progress in urban infrastructure and the provision of essential services, structural challenges persist, particularly in relation to waste management and emission mitigation. These results reinforce the importance of ISO standard indicators as diagnostic instruments and as guidance for improving public policies aimed at urban sustainability.

Keywords: urban sustainability; ISO 37120; urban management; climate change; municipality of Hortolândia

1. Introduction

The topic of sustainable cities has received increasing attention in various parts of the world due to the high concentration of people in strictly urban environments that demand scarce resources. In Brazil, numerous challenges remain in achieving the targets established in the SDGs of the United Nations 2030 Agenda. With specific regard to SDG 11 (Sustainable Cities and Communities), the accelerated urbanization process and the lack of planning observed in most Brazilian municipalities reflect several socio-environmental problems, such as the worsening of the environmental crisis, inadequate basic sanitation, socio-spatial inequality and exclusion, and unemployment [1,2].

Consequently, the growing movement of people toward urban areas increases the demand for infrastructure required by society, transforming this issue into a strategic matter for local governments in promoting sustainable development [3,4]. In this context, the population growth of cities over time has increased pressure on public and private managers to adopt structures and services that better meet community needs while simultaneously contributing to environmental preservation [2,5].

According to the United Nations World Urbanization Prospects report, the global population is expected to increase by approximately forty percent by 2050, reaching nearly ten billion people. Of this total, it is estimated that about sixty-five percent will live in cities [1,6]. This trend reinforces the central role of urban spaces as the stage for the main economic, social, and environmental transformations of the twenty-first century, as already emphasized by initiatives such as the United Nations New Urban Agenda (2017) and by studies that highlight the strategic role of urban planning in promoting more resilient and sustainable cities.

Brazil has one of the highest urban population rates in the world and is the seventh most populous country globally [7]. In 2018, according to the United Nations, eighty-seven percent of Brazilians already lived in cities. This scenario intensifies environmental imbalances and social problems, directly affecting quality of life [8].

Although the literature on sustainable cities and urban development has advanced significantly over recent decades, important gaps still persist regarding the empirical application of standardized sustainability indicators in medium-sized municipalities embedded in complex metropolitan contexts. Even in urban systems with high institutional maturity, the use of these indicators faces methodological limitations and data deficits, highlighting even greater challenges in medium-sized cities subjected to strong metropolitan pressures [9].

A preliminary search conducted in high-impact scientific journals reveals the absence, in recent years, of empirical studies specifically focused on medium-sized Brazilian municipalities located within metropolitan regions and analyzed through the lens of ISO 37120, suggesting that this research agenda remains at an early stage of development. Although a substantial portion of the literature on sustainable cities and urban development concentrates on capital cities or large urban centers, where greater data availability and institutional capacity facilitate the application of sustainability indicators [10], municipalities experiencing accelerated population growth and intense pressure on infrastructure, such as Hortolândia, remain relatively underexplored from this analytical perspective. Furthermore, many studies are limited to the measurement of indicators without advancing toward a deeper analysis of institutional capacities, governance constraints, and the strategic implications for sustainable public policymaking. Studies that interpret the absence or insufficiency of data as evidence of institutional fragility and limitations in municipal urban monitoring systems are also scarce.

In this context, the need for studies capable of moving beyond the mere quantitative assessment of indicators and promoting a critical analysis of the capacity of Brazilian municipalities to structure evidence-based urban management systems aligned with the Sustainable Development Goals and international urban sustainability guidelines becomes evident. In this regard, the case study of Hortolândia gains scientific relevance by investigating a reality that remains insufficiently addressed in the literature, thereby contributing to a broader understanding of the institutional, governance, and monitoring challenges faced by medium-sized cities in implementing urban management systems based on standardized sustainability indicators.

The research problem consists of analyzing the extent to which the performance of the municipality of Hortolândia-SP, assessed through the core urban sustainability indicators established by ISO 37120, reveals not only advances and limitations related to urban sustainability, but also institutional capacities, governance fragilities, and structural challenges associated with the management of medium-sized Brazilian cities situated within complex metropolitan environments. The study also seeks to understand how the availability, insufficiency, or absence of specific data may reflect limitations in municipal systems of urban monitoring and evidence-based management, as well as the implications of these limitations for the formulation of public policies aligned with the SDGs and international urban sustainability guidelines.

The objective of this study is to analyze the performance of the municipality of Hortolândia-SP in light of the core urban sustainability themes defined by ISO 37120—water, wastewater, energy, solid waste, environment, and climate change—identifying advances and limitations in local governance while discussing institutional and public policy implications applicable to other urban contexts.

Tomadon et al. highlight that studies addressing the indicators adopted by governmental agencies are highly relevant, as such indicators play a central role both in monitoring progress and in the formulation of evidence-based policies aimed at promoting sustainable urban development [11].

2. Theoretical Framework

Sustainable development in the urban context can be achieved through high-quality public policies that promote efficient systems for transportation, energy, drinking water supply, wastewater treatment, waste collection and treatment, air quality management, among other services [12]. Urban indicators help measure population vulnerability and the effectiveness of public policies in promoting a safe and sustainable urban environment [13].

In this sense, the application of indicators not only provides a clear understanding of urban reality but also guides the implementation of public policies and strategic actions that foster long-term sustainability [14].

Several studies emphasize the importance of effective public policies and sustainability indicators in guiding urban planning and environmental management, particularly in complex urban contexts such as São Paulo and other Brazilian cities [1,15–17]. In this regard, research suggests that the adoption of international indicators and metrics can assist in aligning these strategies and monitoring progress [4].

Mizutani and Conti (2021) examine how sustainability indicators can be used as management tools in urban planning, highlighting the case of the city of Barueri, São Paulo, and demonstrating how the implementation of these indicators can improve the efficiency of public policies [18]. Similar results were identified by Mecca, Gaballo, and Todella, who emphasize the importance of standardized instruments to measure performance and guide strategic decision-making [4]. Ribeiro, Cortese, and Conti discuss the role of indicators as governance tools as cities expand and require improvements in quality of life. They argue that such indicators are essential for supporting cities on the path toward sustainability by providing critical data for decision-making and for monitoring the implementation of public policies [19]. This perspective aligns with the understanding that systematic measurement is a fundamental condition for continuous improvement and accountability in urban management [15,20].

Ribeiro, Cortese, and Conti also emphasize the relevance of the ISO 37120 standard, as it represents the first regulatory framework specifically designed for cities, bringing together indicators of service efficiency and urban performance [19]. These authors seek to understand how this standard, in conjunction with SDG 11, can support decision-making processes aimed at improving the well-being of urban populations. This perspective is also supported by Merino-Saum et al. and by Myeong, Jung, and Lee, who highlight the importance of standardized metrics in promoting transparency and urban governance [15,20].

However, Thomas, Hsu, and Weinfurter argue that the application of sustainability indicators is complex and often inadequate for measuring progress toward the SDG 11 target of sustainable and inclusive urban areas [21]. In this context, it is important to emphasize the need to use indicators that are appropriately designed for urban contexts, considering their specific characteristics and local realities [4,5].

The ISO 37120 standard establishes indicators to measure urban sustainability across several dimensions, including energy, wastewater, water, environment and climate change, and solid waste. It is an international standard designed to help cities measure their performance, promote consistent comparisons, and implement continuous improvements [5,15].

Spiri-Ferreira et al. state that Brazilian municipalities may adopt the Brazilian technical standard ISO 37120 as a management reference, as it addresses the sustainable development of communities through indicators related to urban services, quality of life, and metrics that enable the measurement and comparison of municipal sustainable development [22].

According to the World Council on City Data, ISO 37120 constitutes the first international standard specifically directed toward cities. Published in 2018, the WCCD has since worked with approximately one hundred cities across thirty-five countries, supporting data reporting in accordance with the standard and assisting cities in obtaining ISO certification. The ISO 37120:2021 version was expanded to include nineteen themes and one hundred twenty-eight key performance indicators (KPIs). These indicators are organized according to themes related to urban sectors and services and are classified as core indicators and supporting indicators. Core indicators are understood as essential for guiding and evaluating the performance of services provided and the quality of life of the population. Supporting indicators are submitted under the international standard with the purpose of encouraging the adoption of best practices. Profile indicators provide statistical and basic information that assist cities in identifying other relevant locations for comparative purposes. Although certification is not its primary objective, ISO 37120 establishes valuable guidelines for urban managers [23].

By establishing indicators to measure urban sustainability across several dimensions, ISO 37120:2021 enables cities to measure their performance, promote consistent comparisons, and implement continuous improvements. The core indicators of ISO 37120:2021 are considered essential for guiding and evaluating the performance of services delivered and the quality of life of urban populations [4]. For the purposes of this study, the following core themes established in the ISO 37120 standard were adopted:

– Water: access to drinking water and the sustainable management of water resources are fundamental for urban sustainability;
– Energy: energy efficiency and the use of renewable energy sources are crucial for reducing the carbon footprint of cities;
– Wastewater: proper treatment protects public health and water resources;

– Solid waste: efficient solid waste management is vital for reducing pollution and promoting recycling and material reuse;
– Environment and climate change: cities must adopt measures to mitigate climate change and protect the environment.

Despite advances in the use of sustainability indicators, significant gaps still remain in integrating these indicators into effective public policies, either because the data are not collected or because they are collected inaccurately. The lack of precise and up-to-date data, combined with political and institutional resistance, represents an important obstacle that must be overcome.

Therefore, the development of studies aimed at monitoring and evaluating core urban sustainability indicators becomes essential in order to assess the extent to which city performance contributes to the construction of more sustainable territories. The establishment and adoption of criteria capable of supporting such evaluations constitute strategic instruments of municipal governance, particularly when accompanied by monitoring systems able to measure the effectiveness of implemented governmental programs [4,24].

Based on the theoretical discussion presented above, Figure 1 illustrates the conceptual model adopted in this study.

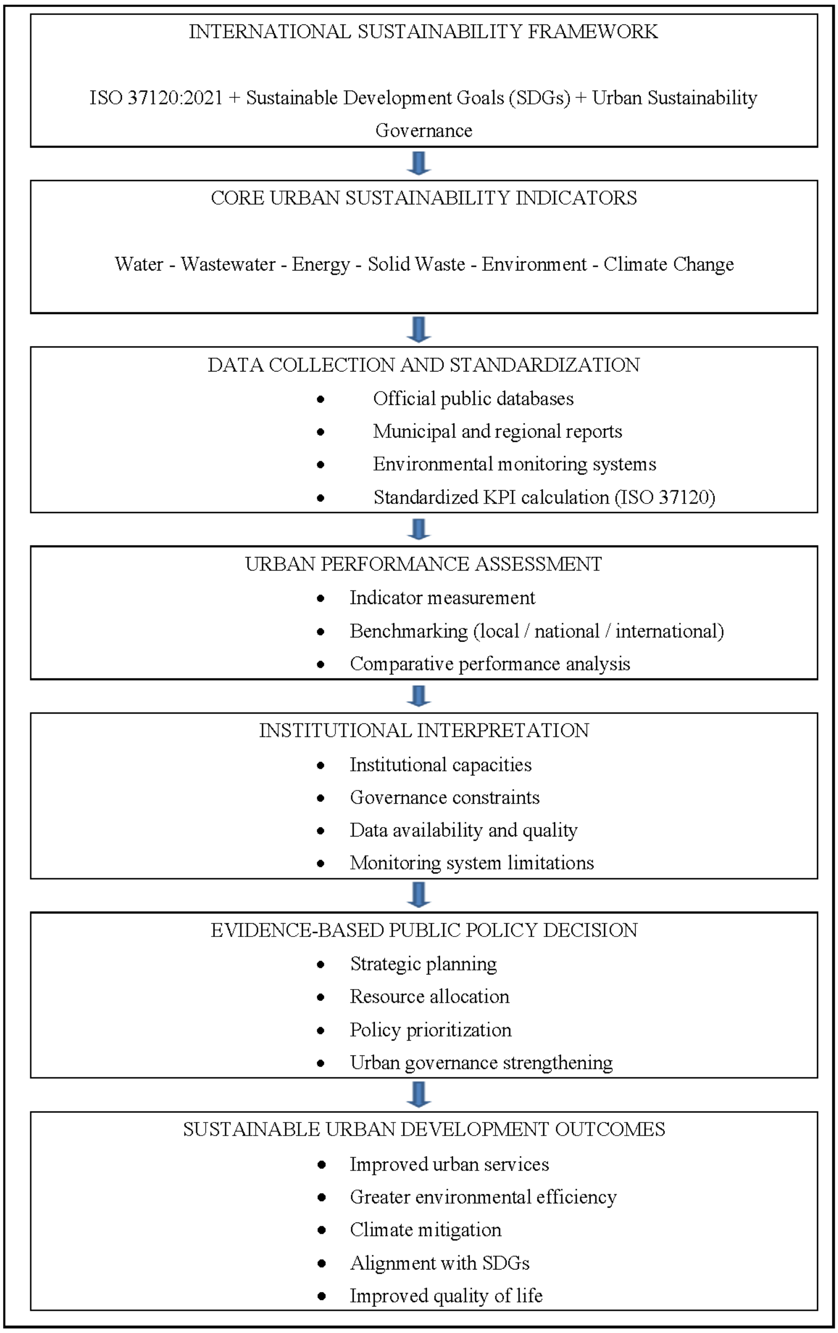

Figure 1. Conceptual model of the ISO 37120-based urban sustainability indicator system. Source: Prepared by the authors (2026).

The model illustrates how ISO 37120 core indicators support urban performance assessment and enable the interpretation of institutional capacities, governance constraints, and monitoring limitations, ultimately contributing to evidence-based public policymaking and sustainable urban development.

3. Materials and Methods

3.1. Study Area: Hortolândia, São Paulo, Brazil

Hortolândia is a medium-sized municipality located in the state of São Paulo, in southeastern Brazil, approximately 115 km from the state capital, São Paulo, and part of the Campinas Metropolitan Region (CMR), one of the most economically dynamic regions in the country. The municipality has a territorial area of 62.416 km^2 and, in 2022, had a population of 236,641 inhabitants and a GDP per capita of approximately US\$15,000, resulting in high demographic density and significant pressure on urban infrastructure [25]. Figure 2 shows the geographic location of the city of Hortolândia within the region and the country.

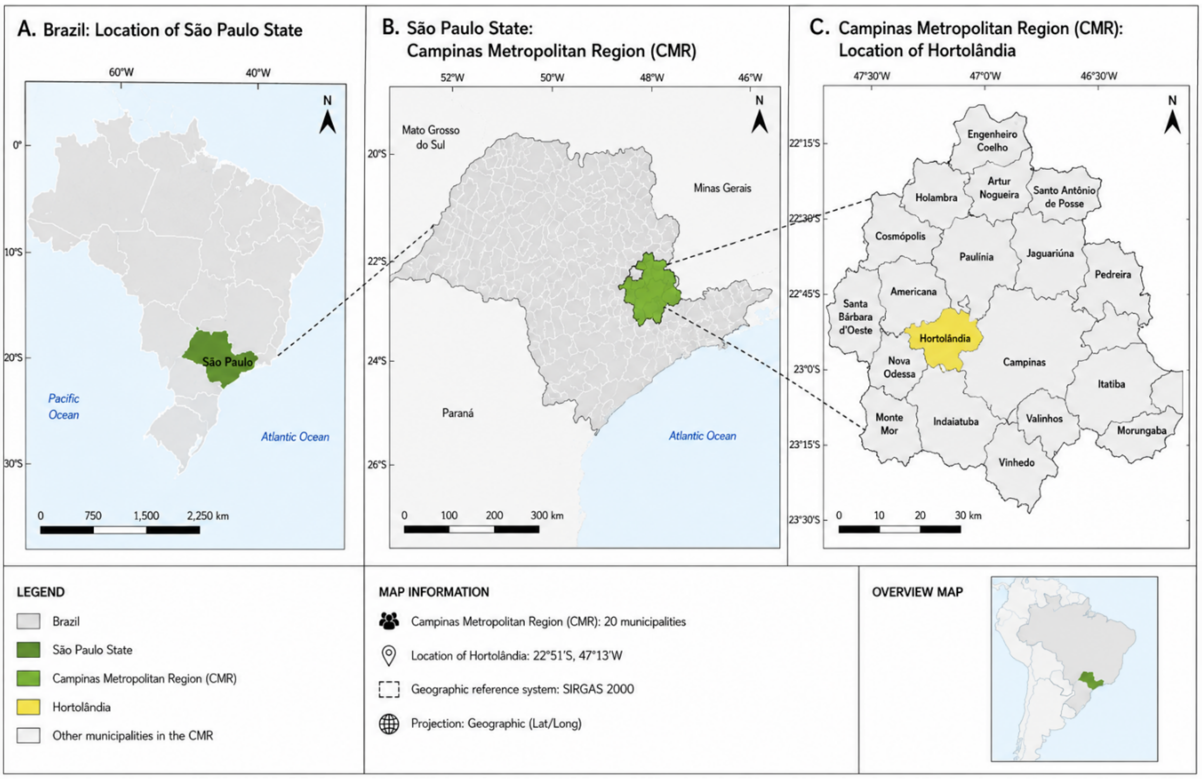

Figure 2. Geographic location of Hortolândia in São Paulo State and the Campinas Metropolitan Region, Brazil. Source: Prepared by the authors (2026).

Over recent decades, Hortolândia has experienced accelerated urban expansion driven by industrialization, the consolidation of logistics infrastructure, the establishment of technology parks, and, more recently, the expansion of data centers. This economic dynamism has attracted investments in advanced manufacturing, renewable energy, and digital technologies, contributing to rapid territorial transformation and strengthening the municipality as an important industrial and technological hub within the metropolitan context. As a result, this growth has increased demand for essential urban services, including water supply, sanitation, energy, solid waste management, and environmental monitoring.

In recent years, the municipality has also gained national and international recognition for innovative initiatives focused on sustainability and the modernization of public management. In 2023, Hortolândia received the Inova Cidade Award for developing a digital platform for project approval aligned with the municipal "Papel Zero" policy [26]. In the same year, it was internationally recognized as one of the 168 Tree Cities of the World by the Foundation Arbor Day and participated in the World Forum on Urban Forests [27]. In 2024, the municipality stood out at the Smart City Expo Curitiba as one of the three best cities in the country in the Sustainable City category, due to energy efficiency initiatives, including the implementation of 21 solar power plants and the universalization of LED public lighting, with more than 23,000 lighting points [28]. In the field of basic sanitation, the municipality also demonstrates strong performance, ranking second among large municipalities in the ABES Universal Sanitation Ranking [29].

Despite these advances, Hortolândia faces sustainability challenges typical of medium-sized metropolitan cities, including increasing greenhouse gas emissions, growing pressure on urban infrastructure, still limited circular economy performance, dependence on landfill waste disposal, and rising energy demand associated with industrial and digital expansion. These challenges are further intensified by metropolitan integration, commuting flows, and increasing pressure on land use and occupation.

In this context, the selection of Hortolândia as the unit of analysis is justified by its location within a highly dynamic metropolitan region, its accelerated urban and economic growth, and the availability of consolidated public data compatible with ISO 37120 indicators. These characteristics make the municipality a particularly relevant empirical case for assessing urban sustainability in Brazilian medium-sized cities, especially with regard to the relationship between infrastructure performance, institutional capacity, evidence-based governance, and the formulation of sustainability-oriented public policies.

3.2. Methodological Research Design

To meet the objectives of this study, the research was designed according to Gil [30]: its nature is applied, its approach is quantitative-descriptive, and its strategic objective is exploratory, using techniques that allow the identification and evaluation of the implementation of public policies carried out in the municipality of Hortolândia, São Paulo.

In order to ensure the transparency and credibility of the results presented in this study, a rigorous process of data collection and analysis was implemented. This section details the data sources used, the methods of data collection and analysis, as well as the data validation procedures. The analyzed period corresponds to the most recent data available in a systematic and comparable form in the official databases consulted.

Regarding the sources, the data used in this study were collected from several reliable secondary sources, including the National Sanitation Information System (SINISA), the Brazilian Institute of Geography and Statistics (IBGE), the São Paulo State Secretariat for Infrastructure, Logistics and Environment (SIMA), the Environmental Company of the State of São Paulo (CETESB), and the Basic Sanitation Company of the State of São Paulo (SABESP). These sources provide official and updated data on different aspects of urban sustainability, such as water, wastewater, energy, solid waste, and air quality.

With regard to the data collection methods, the data were obtained through documentary research, which included official documents such as strategic plans, annual reports, statistical yearbooks, and technical documents published by municipal and state agencies, as well as scientific articles addressing urban sustainability indicators.

Concerning the method of data analysis, the analysis followed the following steps: (a) data organization, consisting of the classification of the collected data according to the core indicators established by the ABNT NBR ISO 37120 standard [31]; (b) calculation of indicators, involving the application of specific formulas to calculate sustainability indicators. For example, the percentage of the population served by wastewater collection was calculated based on the ratio between the population served and the total population of the municipality; (c) comparison of the results obtained with regional and national benchmarks in order to assess the performance of the municipality of Hortolândia. The use of standardized indicators promoted by international organizations favors the comparability and reproducibility of analyses, although it may limit the incorporation of local specificities [15].

The operationalization of the indicators followed the conceptual and methodological definitions established by ABNT NBR ISO 37120:2021. To ensure transparency, reproducibility, and comparability, each indicator was calculated using standardized formulas, explicitly specifying numerators, denominators, units of measurement, reference year, and official data sources (Table 1). When direct municipal data were unavailable, methodological approximations based on regional or metropolitan data were employed, duly identified and justified.

The results are presented in a structured format, organized by the following topics: water, wastewater, energy, solid waste, the environment, and climate change. The selection of the core themes—energy, wastewater, water, environment and climate change, and solid waste—is justified because they represent structuring dimensions of urban sustainability and are directly linked to the core indicators of ISO 37120:2021, which are considered fundamental for evaluating the performance of public services and quality of life in cities. These areas concentrate direct impacts on public health, the rational use of natural resources, emission mitigation, and the management of environmental externalities, while also reflecting the institutional capacity of municipalities to plan, monitor, and implement evidence-based public policies. Therefore, the selection of these themes allows for an integrated and comparable analysis of sustainable urban development, aligned with international guidelines and with the practical demands of municipal management.

Table 1. Core urban sustainability indicators from ISO 37120 applied to the municipality of Hortolândia-SP.

Theme	ISO 37120 Indicator	Formula	Numerator	Denominator	Unit	Source	Year	Adaptation
Water	Population with access to water supply	(Served population/Total population) × 100	Population served	Total population	%	SINISA	2023	None
Water	Per capita domestic water consumption	Volume consumed/Served population	Annual volume consumed	Population served	L/person/day	SINISA	2023	Annual-to-daily conversion
Wastewater	Wastewater collection coverage	(Served population/Total population) × 100	Population served	Total population	%	SINISA	2023	None
Waste	Recycling rate	(Recycled mass/Total mass collected) × 100	Recycled waste	Total waste	%	Instituto Água e Saneamento	2021	Indirect municipal data
Energy	Renewable energy	(Renewable energy/Total energy) × 100	Renewable energy	Total energy	%	SIMA	2023	Use of the São Paulo grid
Climate	GHG emissions	Total reported emissions	Tonnes of CO2e	-	Tonnes of CO_{2e}	SIMA	2023	Regional scale

Source: Prepared by the authors (2026).

4. Results and Analysis

To evaluate municipal actions, data from the municipality were analyzed based on five core indicators established by ABNT NBR ISO 37120 (water, wastewater, solid waste, energy, environment, and climate change). These indicators are considered strategic for guiding urban management and assessing municipal performance.

4.1. Water

The water theme is divided into four indicators and reflects municipal actions related to the availability, consumption, and quality of public water supply. The indicators presented in Table 2 assess access to, availability of, and quality of potable water in the municipality of Hortolândia.

Table 2. Indicators related to water resources in the municipality of Hortolândia.

Water Indicator	Result	Source
Percentage of the city’s population with access to potable water supply services	93.15%	[32]
Percentage of the city’s population with sustainable access to an adequate source of water for consumption	93.15%	[32]
Total domestic water consumption per capita (L/person/day)	154.58	[32]
Compliance rate of drinking water quality	99.89%	[33]

Source: Prepared by the authors (2026).

Hortolândia presents potable water supply coverage of 93.15%, exceeding both the national average (84.9%) and the Southeast regional average (90.9%) reported by SINISA, thereby indicating a trend toward universalization [32]. Per capita water consumption of 154.58 L/person/day also surpasses the minimum threshold of 110 L/person/day recommended by the United Nations to meet basic consumption and hygiene needs [34].

ISO 37120 [31] considers potable water quality compliance to be a core indicator. In Brazil, drinking water standards are regulated by Consolidation Ordinance No. 05/2017 and subsequent updates, encompassing physical, chemical, and microbiological parameters such as color, turbidity, residual chlorine, total coliforms, and *E. coli*.

According to SABESP’s Annual Water Quality Report, Hortolândia achieved 99.89% compliance in potable water quality analyses, based on a minimum sampling of 159 monthly tests [32]. This result demonstrates high efficiency in water quality control and alignment with World Health Organization guidelines concerning the absence of priority fecal and chemical contamination [35].

4.2. Wastewater

The wastewater theme comprises three indicators covering collection, conveyance (transport), and treatment. Table 3 presents the results for Hortolândia.

Table 3. Indicators relating to wastewater in the municipality of Hortolândia.

Wastewater Indicator	Result	Source
Percentage of the city's population served by wastewater collection and disposal systems	93.52%	[36]
Percentage of the city's wastewater that receives centralized treatment	100%	[36]
Percentage of the population with access to improved sanitation	Not available	-

Source: Prepared by the authors (2026).

Basic sanitation, in accordance with ABNT NBR ISO 37120 [31], encompasses indicators related to wastewater collection, conveyance, and treatment, enabling the assessment of the availability and efficiency of the sanitary infrastructure in the municipality of Hortolândia.

According to SINISA, 93.52% of the population of Hortolândia is served by wastewater collection and conveyance systems, a percentage significantly higher than the national average of 53.2% [36]. Despite this strong performance, the municipality has not yet fully achieved SDG 6 Target 6.2, which aims to ensure universal and equitable access to safe sanitation by 2030 [37].

Hortolândia stands out for treating 100% of the wastewater collected within the municipality [36]. At the global level, approximately 56% of domestic wastewater receives safe treatment, indicating that the municipality performs above the international average [38]. However, no information is available regarding the percentage of the population with access to improved sanitation.

4.3. Energy

Reducing energy consumption is essential for preserving natural resources and mitigating greenhouse gas emissions associated with energy generation from fossil fuels. In this context, ABNT NBR ISO 37120 [31] establishes five indicators aimed at evaluating the energy performance of cities. Table 4 presents the results for the municipality of Hortolândia regarding energy availability and consumption.

Table 4. Indicators related to energy resources in the municipality of Hortolândia.

Energy Indicator	Result	Source
Total final energy consumption per capita (GJ/person/year)	9.108	[39]
Percentage of total final energy derived from renewable sources	78.8%	[39]
Percentage of the city's inhabitants with regular residential electricity supply	99.9%	[40]
Number of gas distribution service connections per 100,000 inhabitants	Not available	-
Final energy consumption of public buildings (GJ/year)	31,304.99	[39]

Source: Prepared by the authors (2026).

According to SEADE [40], Hortolândia presents per capita energy consumption of 9.108 GJ/person/year (2,530 kWh/person/year), a value lower than the national average of 2,698 kWh/person/year [41]. The municipality also stands out for adopting clean energy projects and modernizing public lighting infrastructure, thereby contributing to greater energy efficiency.

Regarding renewable energy sources, considering the São Paulo State energy grid, 78.8% of the energy consumed originates from renewable sources, according to SEADE data, indicating a strong participation of clean energy sources within the regional energy matrix [42].

Reliable electricity supply reaches 99.9% of the population of Hortolândia, demonstrating a trend toward universal access to electricity. By comparison, approximately 92% of the global population has access to electricity, while only 17.9% of total final energy consumption worldwide is derived from renewable sources [43]. However, no information is available regarding the number of gas distribution service connections per 100,000 inhabitants, as recommended by ABNT NBR ISO 37120 [31].

With respect to energy consumption in public buildings, Hortolândia presents an average annual consumption of 31,304.99 GJ [42]. In response, the municipal government has expanded investments in photovoltaic energy generation to meet the energy demand of public buildings.

The high share of renewable energy sources and the implementation of energy efficiency projects demonstrate the municipality's commitment to reducing dependence on fossil fuels and mitigating greenhouse gas emissions. Among the implemented initiatives, the Energy Efficiency Program stands out, providing for the installation of 21 photovoltaic power plants capable of supplying approximately 80% of the municipality's 199 public buildings [28].

4.4. Solid Waste

Solid waste management constitutes a strategic issue due to the environmental and public health impacts resulting from the inadequate handling of urban waste. In this context, ABNT NBR ISO 37120 [31] establishes five core indicators aimed at evaluating municipal performance in this area, including the availability of waste collection systems, recycling, solid waste disposal, and treatment through energy generation facilities. The results related to solid waste management in the municipality of Hortolândia are presented in Table 5.

Table 5. Indicators related to solid waste in the municipality of Hortolândia.

Solid Waste Indicator	Result	Source
Percentage of the city's population with regular municipal solid waste collection (household)	100%	[44]
Total municipal solid waste collection per capita	0.66 kg/person/day	[44]
Percentage of municipal solid waste disposed of in sanitary landfills	98.97%	[44]
Percentage of municipal solid waste that is recycled	1.03%	[45]
Percentage of municipal solid waste treated in waste-to-energy plants	Not available	-

Source: Prepared by the authors (2026).

Hortolândia has achieved universal public collection of municipal solid waste, serving 100% of the urban population. In addition, per capita waste generation is 0.66 kg/person/day, a value lower than the national average of 0.98 kg/person/day [44].

At the global level, only 60% to 75% of municipal solid waste is regularly collected, meaning that between 2.0 and 2.7 billion people still lack access to adequate waste collection services [46].

Regarding final disposal, 98.97% of the solid waste generated in Hortolândia is sent to sanitary landfills [44]. Although sanitary landfills are recognized by the Brazilian National Solid Waste Policy as an environmentally appropriate alternative after all possibilities for reuse and recycling have been exhausted (Federal Law No. 12,305/2010), this scenario highlights significant opportunities for improving waste valorization and recovery.

The municipality's recycling rate is only 1.03% of municipal solid waste [45], a percentage even lower than Brazil's already low national recycling rate of 4% for municipal solid waste [44]. Globally, approximately 20% to 25% of municipal solid waste is recycled, with averages approaching 50% in high-income countries and approximately 16% in low-income countries [47]. No information was found regarding the percentage of municipal solid waste treated in waste-to-energy facilities.

4.5. Environment and Climate Change

Climate change constitutes one of the main contemporary challenges faced by cities, producing environmental, social, and economic impacts that already directly affect urban dynamics [48]. In this context, the Environment and Climate Change indicators used in this study assess air quality and greenhouse gas emissions in the municipality of Hortolândia, in accordance with ISO 37120 parameters.

In the state of São Paulo, CETESB continuously monitors air quality through automated atmospheric pollutant monitoring stations. The indicators were classified according to the annual average concentrations of particulate matter (PM10 and PM2.5), based on the air quality standards established by CETESB [49] for the municipality of Hortolândia (Table 6).

With respect to Indicator 1, air quality constitutes a central issue within environmental and public health agendas, particularly due to the impacts of fine particulate matter on climate and urban quality of life. In this context, ABNT NBR ISO 37120 [31] establishes the concentration of particulate matter with a diameter equal to or smaller than 2.5 µm (PM2.5) as a core indicator. In Hortolândia, the recorded annual average concentration was 14 $\mu g/m^3$, classified as "Good" by [49].

Table 6. Indicators related to the environment and climate change in the municipality of Hortolândia.

Environment and Climate Change Indicator	Result	Air Quality Classification	Source
PM_{10} particulate matter concentration—annual average concentration (μg/m^3)	21	Good	[49]
Fine particulate matter concentration—PM2.5—annual average concentration (μg/m^3)	14	Good	[49]
Greenhouse gas emissions	203.5×10^3 tonnes CO_2e	-	[50]

Source: Prepared by the authors (2026).

Regarding Indicator 2, ISO 37120 [31] considers the measurement of the annual average concentration of inhalable particulate matter PM10, with a diameter equal to or smaller than 10 μm, to be essential. In Hortolândia, the annual average PM10 concentration was 21 μg/m^3, also classified as "Good" by CETESB [49].

Indicator 3 refers to greenhouse gas (GHG) emissions, recognized as one of the major global environmental urgencies associated with climate change. According to SIMA [50], Hortolândia presented estimated emissions of 203.5×10^3 tonnes CO_2e, an indicator considered essential by ABNT NBR ISO 37120 [31].

5. Discussion and Implications

5.1. Urban Performance and Indicator Heterogeneity

The analysis of the essential indicators of ISO 37120 shows that Hortolândia presents heterogeneous performance in urban sustainability, combining significant advances in sanitation, energy, and environmental quality with structural limitations related to the circular economy, greenhouse gas (GHG) emissions, and institutional monitoring capacity. The use of structured benchmarking enabled the comparison of the municipality's results across three complementary scales: (i) the Brazilian national average; (ii) international references and SDGs targets; and (iii) comparable urban experiences in Brazilian municipalities. This strategy strengthens the comparability of the results and broadens the interpretation of the indicators beyond simple numerical measurement.

In the water sector, Hortolândia achieved water supply coverage of 93.15%, exceeding the national and regional averages reported by SINISA, in addition to high compliance in drinking water quality (99.89%) [32]. These results demonstrate consistent institutional capacity in urban water management and adherence to the principles of SDG 6 and ISO 37120 related to safe access to water. Bain, Johnston, and Slaymaker emphasize that water quality constitutes a central dimension of public health and the reduction of socio-environmental vulnerabilities [35]. However, the fact that approximately 7% of the population remains unserved indicates that universal access has not yet been achieved, maintaining risks of territorial inequality and sanitation exclusion. Furthermore, high per capita water consumption suggests the need for more robust policies on water efficiency, reuse, and environmental education, particularly in metropolitan contexts marked by increasing pressure on natural resources [51].

Wastewater indicators show strong municipal performance: Hortolândia treats 100% of collected wastewater and has collection coverage above the Brazilian average. This aligns with SDG 6 and reinforces sanitation's role in public health, water-resource protection, and urban sustainability, as argued by Silva [52].

In the energy sector, Hortolândia presents relatively positive performance, with near-universal residential electricity access (99.9%) and a high share of renewable energy sources (78.8%), a percentage significantly higher than the global average reported by the United Nations [43]. Investments in LED public lighting and photovoltaic plants demonstrate alignment with energy transition guidelines and SDG 7. Werner and Lazaro emphasize that the expansion of renewable energy depends on coordination among states, municipalities, and private investments, especially in emerging economies [53]. However, the high absolute energy consumption in public buildings indicates the need to deepen energy efficiency policies, audits, and retrofit programs.

Overall, the results reinforce the relevance of ISO 37120 as an instrument for urban governance, institutional diagnosis, and public policy monitoring. Ribeiro, Cortese, and Conti highlight that the articulation between ISO 37120 and the SDGs strengthens cities' capacity to translate global goals into comparable local metrics [19]. In the case of Hortolândia, direct connections can be observed between the analyzed indicators and SDGs 6 (water and sanitation), 7 (clean energy), 11 (sustainable cities), 12 (responsible consumption and production), and 13 (climate action). This integration expands the potential of the standard as a strategic tool for sustainable urban planning.

5.2. Institutional Capacities and Governance Constraints

However, the indicator related to population access to improved sanitation appears as "not available". This absence of data should not be interpreted merely as an operational limitation of the research, but rather as evidence of institutional fragility related to the production, integration, and transparency of urban information. Thomas, Hsu, and Weinfurte warn that the absence or poor quality of data compromises the effectiveness of urban indicators and limits their capacity to support strategic decision-making [21]. Thus, data unavailability itself constitutes an important finding of this study, revealing limitations in local urban governance and monitoring systems.

Furthermore, the indicator related to gas connections per 100,000 inhabitants is also unavailable. This gap reveals insufficient integration among public energy infrastructure databases and reinforces the need for more robust urban monitoring and data transparency systems.

Another relevant aspect concerns institutional limitations associated with environmental measurement. The municipality does not have its own air quality monitoring station, making methodological adaptation necessary through the use of CETESB regional data. Although methodologically justifiable, this limitation reveals institutional dependence on state-level environmental monitoring systems. Thomas, Hsu, and Weinfurter observe that medium-sized cities often face technical and financial difficulties in producing complete and continuous urban indicators, compromising diagnostic accuracy and evidence-based governance [21].

5.3. Structural Challenges of Circularity and Decarbonization

Solid waste management represents the main point of fragility identified in the municipality. Although Hortolândia has universalized household waste collection, its recycling rate of only 1.03% demonstrates strong dependence on a linear management model based on final disposal in landfills. This result is significantly lower than the international averages reported by Shovon et al., who indicate recycling rates close to 20% to 25% globally [47]. The predominance of landfilling reflects limited incorporation of circular economy principles established in the National Solid Waste Policy (PNRS). Lino, Ismail, and Castañeda-Ayarza emphasize that the persistence of this linear model constitutes one of the main barriers to Brazilian urban sustainability [54].

In this context, the discussion on circular economy becomes central. Low waste valorization reflects the loss of economic, energy, and environmental opportunities related to material recovery, income generation, and emission reductions associated with landfilling. Xia et al. demonstrate that permanent environmental education programs, structured selective collection, and economic incentives significantly increase recycling rates [55]. In addition, the indicator related to waste treatment in energy recovery facilities also appears as "not available", revealing not only the absence of data but also the likely absence of municipal infrastructure dedicated to energy recovery from waste. This gap reinforces the need for transition toward circular models based on reverse logistics, material reuse, biodigestion, and waste-to-energy solutions, especially in metropolitan municipalities with high waste generation.

Environmental and climate change indicators reveal an ambivalent scenario. On the one hand, Hortolândia presents air quality classified as "good" for PM10 and PM2.5, demonstrating relative control of local atmospheric emissions. Vandyck et al. emphasize that air quality policies have direct impacts on public health and urban quality of life [56]. However, the magnitude of GHG emissions (203.5×10^3 tonnes CO_2e) highlights an important climate challenge for the municipality. This aspect becomes particularly relevant given industrial growth, logistics expansion, and the installation of data centers in Hortolândia, activities that are intensive in energy consumption and indirect emissions.

The analysis of GHG emissions must be understood from a systemic and territorial perspective. Although the municipality has made advances in energy efficiency and renewable sources, such measures are still insufficient to offset the growth of urban emissions. Ulpiani et al. emphasize that contemporary cities need to integrate climate and air quality policies simultaneously, preventing local gains from masking the persistence of high global emissions [57]. In this sense, Hortolândia may adopt strategies similar to those implemented in Sorocaba, as described by Affonso and Magagnin, including expansion of sustainable public transportation, active mobility, electrification of the urban fleet, and incentives for low-carbon construction [58].

5.4. Public Policy Implications

From a public policy perspective, the results indicate the need for more concrete and integrated recommendations. In the water sector, expansion of service coverage to still-unserved areas, implementation of permanent water reuse and efficiency programs, and strengthening metropolitan water governance are recommended. Sanitation priorities include universal wastewater collection and stronger effluent-quality monitoring. In the energy sector, it is recommended to expand distributed generation programs, improve energy efficiency in public buildings, and promote urban planning oriented toward decarbonization.

In solid waste management, the implementation of structured selective collection programs, strengthening recycling cooperatives, economic incentives for circularity, and the development of energy recovery solutions become priorities. Regarding climate change, the municipality needs to advance in developing continuous local emissions inventories, climate neutrality targets, low-carbon mobility policies, and climate-resilient territorial planning. Furthermore, the absence of data in certain indicators itself highlights the need to strengthen municipal systems of information, transparency, and urban monitoring.

The results demonstrate that Hortolândia has achieved important advances in urban infrastructure and essential service provision, but also reveal limitations typical of medium-sized Brazilian cities embedded in complex metropolitan contexts. Therefore, urban sustainability depends not only on the expansion of physical infrastructure but also on the institutional capacity to produce reliable data, integrate sectoral policies, and transform indicators into effective instruments of governance, planning, and decision-making.

To synthesize the main policy recommendations derived from the ISO 37120 assessment, Figure 3 presents a multi-scale action plan for improving urban sustainability in Hortolândia. The framework organizes priority actions across four complementary governance scales—municipal, metropolitan, institutional, and strategic—highlighting that effective urban sustainability transitions require coordinated interventions that combine infrastructure improvements, governance strengthening, data integration, and long-term climate-oriented planning.

ISO 37120-BASED URBAN SUSTAINABILITY ASSESSMENT

Water - Wastewater - Energy - Solid Waste - Environment - Climate Change

KEY FINDINGS FROM HORTOLÂNDIA

Strengths

- High water quality (99.89%)
- High wastewater treatment (100%)
- Nearly universal electricity access (99.9%)
- High renewable energy share (78.8%)
- Good air quality (PM2.5 and PM10)

Critical Gaps

- Low recycling rate (1.03%)
- High dependence on landfill disposal
- Significant GHG emissions (203.5×10^3 tonnes CO_2e)
- Missing data for sanitation and gas indicators
- Lack of local air monitoring station

MUNICIPAL SCALE Short-term actions	**METROPOLITAN SCALE Regional coordination**	**INSTITUTIONAL SCALE Governance capacity**	**STRATEGIC SCALE Long-term transition**
WATER • Expand coverage • Reduce losses • Promote reuse	Integrated water governance Shared sanitation planning	Data integration across sectors Urban dashboards (KPI systems)	Circular economy transition Carbon neutrality roadmap
SANITATION • Universal access • Effluent control	Regional waste management	Monitoring systems improvement	Climate resilience planning
ENERGY • Solar expansion • Building retrofit	Clean mobility integration	Interdepartamental coordination	SDG alignment (2030 Agenda)
WASTE • Selective collect • Recycling coops • Waste-to-energy	Shared climate policies	Transparency and open-data systems	Smart sustainability city model
CLIMATE • GHG inventory • Low-carbon transit	Metropolitan GHG reduction strategy	Evidence-based decision-making	Net-zero urban development

EXPECTED SUSTAINABILITY OUTCOMES

- Improved infrastructure performance
- Reduced environmental impacts
- Better institutional governance
- Higher climate resilience
- Evidence-based public policymaking
- Alignment with SDGs and sustainable urban transition

Figure 3. Multi-scale action plan for improving urban sustainability in Hortolândia based on the ISO 37120 assessment. Source: Prepared by the authors (2026).

5.5. Contributions of the Study

The original contribution of this research lies in using ISO 37120 not merely as a technical instrument for measuring urban performance, but as an analytical framework for interpreting institutional capacities, governance fragilities, and the limits of Brazilian municipal management. By focusing on Hortolândia-SP, a medium-sized municipality located within the Metropolitan Region of Campinas, the study expands the empirical scope of the literature, which has traditionally prioritized capital cities, large urban centers, or broader comparative analyses. In this sense, the article's innovation resides in demonstrating that medium-sized metropolitan municipalities constitute strategic spaces for concretely assessing how urban sustainability is conditioned by infrastructure quality, data availability, and the capacity of public authorities to transform indicators into management decisions.

Compared with related studies that apply urban sustainability indicators primarily to describe, rank, or compare cities, this research advances the field by interpreting the results as evidence of institutional capacities and governance asymmetries across different areas of urban policy. The study demonstrates that Hortolândia presents positive performance in water supply and quality, wastewater collection and treatment, access to electricity, and the share of renewable energy sources, while simultaneously revealing significant fragilities in solid waste recycling, dependence on sanitary landfills, and the mitigation of greenhouse gas emissions. These contrasts reveal distinct levels of institutional maturity and planning capacity among strategic sectors of urban management. Thus, the originality of the research lies not only in the calculation of indicators, but also in the critical analysis of the institutional inequalities that condition the implementation of sustainable public policies, particularly in areas still characterized by weak integration, insufficient planning, and limited incorporation of circular economy principles and climate action strategies.

The study also advances the ISO 37120 literature by treating the absence, insufficiency, or adaptation of data as a substantive governance finding rather than merely a methodological limitation. By highlighting indicators that are unavailable or dependent on regional and state-level databases, the research demonstrates that urban sustainability depends on the existence of robust municipal systems of information, monitoring, and evaluation. This approach broadens the understanding of ISO 37120 as an institutional diagnostic tool, as it enables the assessment not only of urban service performance, but also of the municipality's capacity to produce reliable, continuous, and comparable data capable of supporting evidence-based public policies.

Finally, the research contributes to the literature on Brazilian municipal governance and public policy evaluation by integrating urban indicators, the Sustainable Development Goals, and local governance into a unified analytical interpretation. The study demonstrates that ISO 37120 can support the formulation of more objective public policies, particularly in areas such as universalization of services, water and energy efficiency, recycling, waste recovery, emissions inventories, and municipal climate planning. In this way, the article offers an applied and replicable contribution by showing how medium-sized Brazilian municipalities can use standardized indicators not only to measure results, but also to identify priorities, guide investments, strengthen transparency, and improve sustainable urban governance.

6. Conclusions

The analysis of the core ISO 37120 indicators applied to the municipality of Hortolândia-SP demonstrated that urban sustainability must be understood beyond the mere availability of infrastructure and the isolated measurement of urban services. The results revealed that municipal performance reflects differentiated institutional capacities across strategic sectors of urban management, exposing significant asymmetries between more consolidated areas, such as sanitation and energy, and areas still characterized by structural limitations, particularly solid waste management, circular economy practices, and climate mitigation.

The study also demonstrated that the absence, insufficiency, or dependence on external data constitutes important evidence of institutional limitations within municipal urban monitoring systems. In this sense, the research advances the literature by interpreting ISO 37120 indicators not merely as technical measurement instruments, but as analytical mechanisms capable of revealing governance patterns, state capacity, and institutional maturity in medium-sized cities embedded in complex metropolitan contexts.

From a theoretical and methodological perspective, the article expands the understanding of the potential of ISO 37120 as an institutional diagnostic tool and as a mechanism for supporting evidence-based public policymaking. By integrating urban indicators, the Sustainable Development Goals, and municipal governance into a unified analytical framework, the study reinforces that urban sustainability depends not only on the expansion of physical infrastructure, but also on the capacity of municipalities to produce reliable data, integrate sectoral policies, and transform metrics into effective instruments for planning, coordination, and decision-making.

Although the study is limited to a single municipality and to a specific set of core indicators, the findings present analytical and practical potential for other medium-sized Brazilian municipalities subjected to similar metropolitan pressures. Future research may expand the temporal and territorial scope of the analyses, incorporate additional ISO 37120 indicators, and develop comparative models capable of deepening the understanding of the relationships between urban sustainability, institutional governance, and public policy implementation capacity.

Author Contributions

Conceptualization: F.T.d.S.d.S., D.C.C., S.C.D.B. and R.M.L.; Methodology: F.T.d.S.d.S., D.C.C., R.M.L. and D.d.M.C.; Project management: F.T.d.S.d.S., D.C.C. and S.C.D.B.; Supervision: R.M.L. and S.C.D.B.; Data validation: C.F.d.S.F. and S.C.D.B.; Writing—original draft: F.T.d.S.d.S., D.C.C., R.M.L. and S.C.D.B.; Writing—review and editing: D.d.M.C. and C.F.d.S.F. All authors have read and agreed to the published version of the manuscript.

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All data generated or analyzed during this study are included in this published article.

Conflicts of Interest

The authors declare no conflict of interest. Given the role as Editorial Board Member, Diego de Melo Conti had no involvement in the peer review of this paper and had no access to information regarding its peer-review process. Full responsibility for the editorial process of this paper was delegated to another editor of the journal.

Use of AI and AI-Assisted Technologies

During the preparation of this work, the authors used ChatGPT5.3 to polish language. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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