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Sustainability index: application for the municipalities of Ilha do Maranhão.

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ABSTRACT
The article aims to estimate the sustainability index (SI) for the municipalities of Ilha do Maranhão and verify if they adapt to the concepts of sustainable cities discussed in the context of emerging international conferences since the 1980s and more specifically regarding the 2030 Agenda through SDG 11- Sustainable cities and communities. The methodology used was based on applied research for the construction of the IS with the use of quantitative research based on the ABNT indicator system NBR ISO 37120:2017. As an outcome, it was noticed that those indicators are applicable to the municipalities, even with the limitations due to the partial collection of data as well as the obsolete basis for public research. Considering the results obtained for the municipalities, it was identified that they range from acceptable to regular regarding the condition of sustainability and compliance with SDG 11.

Keywords: Sustainability Index; sustainable cities; Ilha do Maranhão.

1 INTRODUÇÃO

The development of action plans in the strategic planning of local governments has been an increasingly emerging need to meet the goals of the 2030 Agenda. The Spotlight Report (2021) evaluated Brazil's path to the implementation of the Sustainable Development Goals (SDG) in the year 2021. According to the results, Brazil is currently among the countries that are considerably further away from the 2030 Agenda, with 54.4% of the goals being set back.

The challenge of meeting the goals established by SDG 11 - which premise is to make cities and communities sustainable - becomes even more complex due to the multiple aspects that are intertwined in the urban space and that directly imply the relation between the environment and human beings. Contemporary urban centers have a direct dependency relation between human needs and the existing infrastructure. Such dependence is reflected in the demands for housing, basic education and health services, job offers, green areas, as well as means of transportation for daily commuting. Regardless of size and population density, the quality of life in cities is intrinsically related to the urban services offered to its inhabitants, both in quantitative and qualitative aspects.

Developing quality of life in urban centers is one of the premises of the sustainable city, as stated by Rogers (2013) "a sustainable city provides quality of life for its citizens and for future generations through solutions that aim to reconcile environmental and social aspects". However, what has been observed over the years is that urban problems have gotten worse, which is - according to Rosseto (2016) – a consequence of disorderly growth, by not meeting the population's demands for resources and services, and also based on the precarious physical infrastructure of cities, the deterioration of the environment and ineffective urban management.

Thus, it is fundamental to observe the aspects of a city from reading data and information that are generated by it on a daily basis. Cities need indicators to measure their performance towards sustainable development. These indicators are important tools for public management to direct investments in order to improve the quality of life of a city's population.

This article aims to search for possible responses for the question: What is the sustainability condition of the municipalities that constitute Ilha do Maranhão, in the state of Maranhão? In order to answer this question, the article was developed based on a structure that describes in detail the methodological steps used to investigate the problem, which led to some outcomes and conclusions. The answers to the proposed question can serve as an analysis standard to diagnose the actual situation of the municipalities of the Island of Maranhão in

considering the progress towards sustainable development and the fulfillment of the goals of SDG 11 of the 2030 Agenda.

2 OBJECTIVES

This article has the general purpose of estimating the sustainability index (SI) for the municipalities of Ilha do Maranhão, and the specific objectives of (1) identifying the indicators capable of measuring the level of sustainability from the municipalities and (2) analyzing the applicability of the system of indicators from the ABNT ISO 37120:2017 technical standard, regarding urban services and people's quality of life, considering the principles of a sustainable city.

3 METHODOLOGY

In this section, we describe the actions and steps taken for the investigation of the research problem. The methodology used in this study had a quantitative nature regarding the approach; and considering its nature, it can be classified as applied research, once it used an instrument that had already been created, with the incorporation of new local technical components. According to Silva and Menezes (2001, p.20), the applied research "aims to generate knowledge for practical application in solving specific problems". In this sense, for better understanding of the study, the first step was to characterize the locus of the research (the municipalities of Ilha do Maranhão). In this characterization, documentary research and a survey about general secondary data of the municipalities were used.

The following step examined the approach to the indicator system adopted, analyzing its relations with the goals of SDG 11 and other SDGs of the 2030 Agenda, and in the subsequent step, the variables significant to this study were defined. The procedures for obtaining data were described, as well as the sources consulted, and then the criteria for building the sustainability index (IS) were defined. Finally, the results obtained were presented, through a ranking of the four municipalities, in order to demonstrate the sustainability index obtained.

3.1 Characterization of the locus of research

What is popularly known as Ilha do Maranhão is an urban agglomeration made up of the municipalities of Raposa, Paço do Lumiar, São José de Ribamar and São Luís – the capital of the State of Maranhão. The IBGE (2015) characterizes this type of population concentration as a "grouping of two or more municipalities where there is a strong population al integration due to commuting or to the contiguity between the main urbanized spots".

The reasons that conducted the investigation of this urban agglomeration, regarding its level of sustainability, considered some factors such as: territorial continuity, environmental unity and the existence of an urban network between municipalities.

Ilha do Maranhão (Figure 1) is in the north of Maranhão, a state in the northeast region of Brazil. It is limited to the North by the Atlantic Ocean, to the East by São José Bay, to the South by Arraial Bay and to the West by São Marcos Bay. It is framed by the geographic coordinates 2° 24` 10" and 2° 46` 37" South latitude and 44° 22` 39" and 44° 22` 39" West longitude. As it is an

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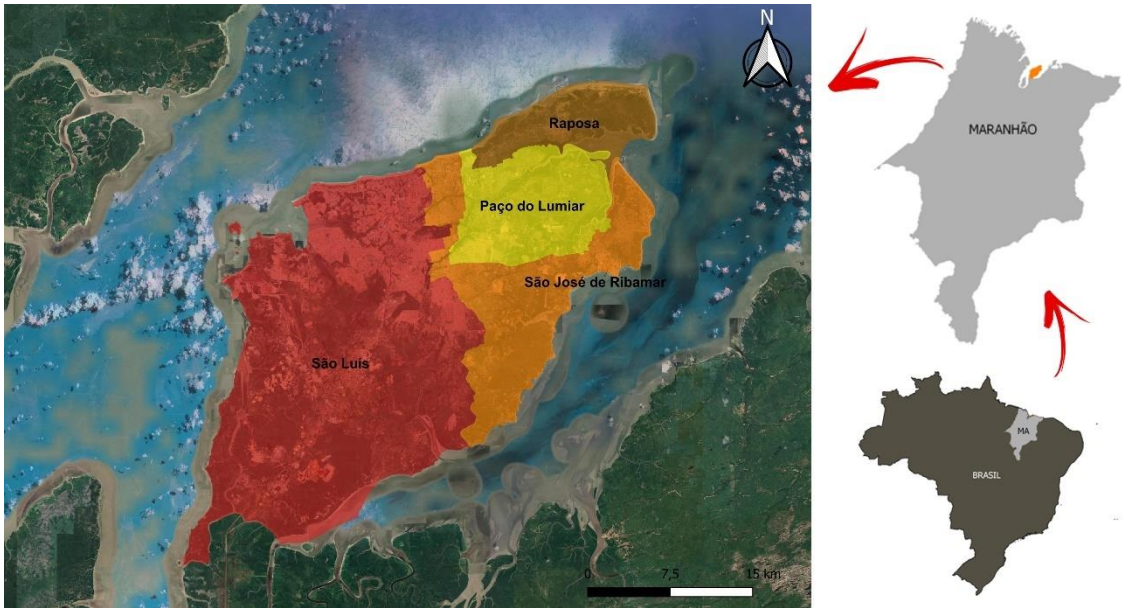
insular territory, Ilha do Maranhão has environmental characteristics that form peculiar landscapes, such as the "extensive mangrove ecosystem, the large number of drainage canals and the types of soil and vegetation found in its space". (IMESC, 2021).

Figure 1 - Geographical location of Ilha do Maranhão and municipalities



Source: Prepared by the author (2022). Google Satellite Image

According to the IBGE Census (2010), the Island of Maranhão covers 1,410.015 km² of land area, home to a population of 1,309,330 inhabitants with an average demographic density of 722 inhabitants/km². The region's GDP corresponds to 37.61% of the state's GDP and the region's HDI average corresponds to 0.7, as shown in Table 1, which presents a summary of the main municipal indicators.

Table 1 - Profile of the municipalities of Ilha do Maranhão

PROFILE OF THE MUNICIPALITIES OF ILHA DO MARANHÃO					
Data	São Luís	S.J. Ribamar	P. do Lumiar	Raposa	Source
Creation (year)	1612	1952	1959	994	IMESC (2020)
Population	1.014.837,00	163.045	105.121	6.327	IBGE (2010)
population density (people per square kilometre.)	1.215,69	419,82	855,84	97,21	IBGE (2010)
Area (square kilometre.)	583,063	180,363	127,193	9,213	IBGE (2010)
GDP (ranking MA)	1	5	13	3	IBGE (2019)
HDI	0,76	0,70	0,72	0,62	IBGE (2010)
Gini index	0,62	0,52	0,50	0,48	IBGE (2010)
IFDM (Firjan)	0,76	0,69	0,63	0,58	FIRJAN (2016)
IGM	5,05	5,81	4,33	3,94	IGM/PCA (2022)
IVS	0,37	0,44	0,44	0,64	IPEA (2010)

Source: Prepared by the author (2022).

The region's economy is mainly focused on the secondary and tertiary sectors, with the highest concentration of transformation and trade industries, as well as horticultural production, poultry, artisanal fishing and tourism in the state of Maranhão. (IMESC, 2021).

From the 1980s onwards, with the implementation of the port complex and the industrial district in São Luís, the island's urbanization process intensified, with the expansion of the urban area of São Luís towards the other municipalities. Currently, the municipalities of São Luís and São José de Ribamar are in the process of urban conurbation, given the contiguity of their urban spots.

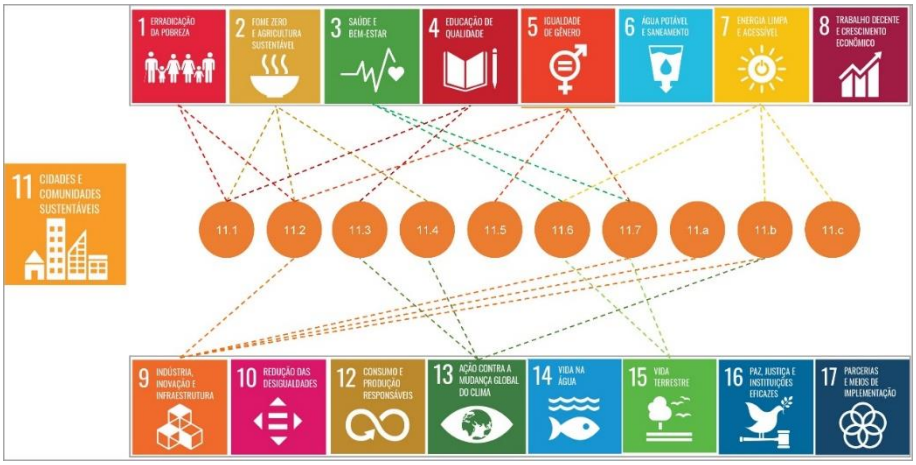
Because of some aspects of its urbanization process, we can summarize that the municipalities of Ilha do Maranhão present a configuration of urban dispersion, with rarefied urban layout, presence of rural areas and dependence on the road modal for daily commuting.

3.2 Selection of sustainability indicators

This research used the indicator system recommended by ABNT ISO 37120:2017 - sustainable cities and communities - indicators for urban services and quality of life. The indicators are grouped into the axes: Economy, Energy, Environment, Water and Sanitation, Sewage, Solid Waste, Recreation, Housing, Urban Planning, Finance, Governance, Education, Health, Transport, Security, Telecommunications and Innovation, Fire Response and Emergencies.

It is important to mention that the ABNT indicator system is directly related to SDG 11, which, given its transversal nature, covers practically the entire 2030 Agenda.

Figure 2 – Relationship of SDG 11 with the other SDGs of the 2030 Agenda for Sustainable Development



Source: Prepared by the author (2022).

ABNT ISO 37120:2017 recommends the use of 100 (one hundred) indicators: 46 out of them are essential indicators (mandatory for the application of the standard rule) and 54 are support indicators (optional for the application of the standard rule). In order to make the analysis in this study more objective, it had been decided for the collection of data that represents only the essential indicators.

3.3 Data Collection

The collection of secondary data was carried out by consulting official public sources: IBGE Demographic Census, the digital platform from the Ministry of Health (DataSUS), National

Traffic Council (Conatran), National Sanitation Information System (SNIS), National Telecommunications Agency (ANATEL), Equatorial Energia Maranhão, National Institute for Space Research (INPE), National Institute for Studies and Research Anísio Texeira (INEP), Annual Social Information Report (RAIS), Brazil's Electoral Court (TSE), Secretariat for Public Security of Maranhão (SSP), obtained through the website of Maranhão's Institute of Socioeconomic and Cartographic Studies (IMESC) and the Master Plan for the Integrated Development of the Metropolitan Region of São Luís (PDDI), as seen on table 2.

Data collection was incomplete due to the non-existence or lack of disclosure of some data to the municipalities. For the Education, Health, Finance, Governance, Security, Housing, Waste, Telecommunications and Urban Planning axes, all essential indicators were collected. For the other axes, the collection was partial and only for the Recreation axis, no data was collected at all. Thus, from 46 essential indicators recommended by ABNT ISO 37120:2017, 32 were collected (Table 2) and considered in this study.

Table 2 - Essential indicators recommended by ABNT ISO 37120: 2017

AXES	ESSENTIAL INDICATORS (ABNT ISO 37120:2017)	AGENDA 2030	SOURCE
ECONOMY	unemployment rate (%)		IBGE/2010
	Appraised value of commercial and industrial properties as a percentage of the total appraised value of all Properties		-
	Percentage of population below the poverty line (%)		IBGE/2010
EDUCATION	Percentage of school-age female population enrolled in schools (%)		INEP/2020 IBGE/2010
	Percentage of students with complete primary education: survival rate (%)		INEP/2020
	Percentage of students with a secondary education: survival rate (%)		INEP/2020
	Student/teacher ratio in primary education		INEP/2020
ENERGY	Total residential electricity use per capita (kWh/year)		EQUATORIAL 2020
	Energy consumption of public buildings per year (kWh/m²)		-
	Percentage of total energy coming from renewable sources, as part of the city's total energy consumption		-
	Percentage of city dwellers with regular electricity supply (%)		IBGE/2010
ENVIRONMENT	Concentration of fine particulate matter (PM 2.5) (µg/m³)		INPE/2018
	Concentration of particulate matter (PM 10)		-
	Emission of greenhouse gases, measured in tons per capita (ton/person)		INPE/2018
FINANCE	Debt ratio (debt service expansion as a percentage of the municipality's own revenue) (%)		IBGE/Siconfi/ STN 2020
FIRE RESPONSE AND EMERGENCIES.	Number of firefighters per 1000 population		RAIS/2020
	Number of fire-related deaths per 1000 population		-
	Number of deaths related to natural disasters per 1000 population		-

GOVERNANCE	Percentage of voter participation in the last municipal elections as a function of the total number of eligible voters (%)		**TSE/2020**
	Percentage of women elected according to the total number of elected in city management (%)		**TSE/2020**
HEALTH	Average life expectancy (years)		**IBGE/2010**
	Number of hospital beds per 1000 population		**DATASUS 2021**
	Number of doctors per 1000 population		**DATASUS 2021**
	Mortality rate of children under 5 years of age per 1000 live births		**DATASUS 2021**
SECURITY	Number of police officers per 1000 population		**RAIS/2020**
	Number of homicides per 1000 population		**SSP/MA; IBGE/2010**
HOUSING	Percentage of urban population living in slums (%)		**IBGE/2010**
SOLID WASTE	Percentage of urban population with regular collection of solid waste (household)		**SNIS/2020**
	Total municipal solid waste collection per capita		**SNIS/2020**
	Percentage of municipal solid waste that is recycled		**SNIS/2020**
TELECOMMUNICATIONS AND INNOVATION	Number of internet connections per 1000 population		**ANATEL/2022**
	Number of cell phone connections per 1000 population		**ANATEL/2022**
TRANSPORT	Number of private cars per capita		**CONTRAN/ 2020**
	Kilometers of high-capacity public transport system per 100.000 population		-
	Kilometers of medium-capacity public transport system per 100,000 population		-
	Annual number of trips on public transport per capita		-
URBAN PLANNING,	Green areas (m^2) per population		**PDDI/GOV ESTADO**
SEWAGE	Percentage of urban population served by sewage collection and disposal systems (%)		**SNIS/2020**
	Percentage of sewage collection, which did not receive any treatment (%)		**SNIS/2020**
	Percentage of city sewage that receives primary treatment		-
	Percentage of city sewage that receives secondary treatment		-
	Percentage of city sewage that receives tertiary treatment		-
WATER AND SANITATION	Percentage of city population with drinking water supply service (%)		**SNIS/2020**
	Percentage of city population with access to a source of water suitable for consumption		-
	Percentage of city population with access to improved sanitation (%)		**IBGE/2010**

	Total household water consumption per capita (liters per day)		-

Source: Prepared by the author (2022).

The collection of data was based on official websites, publications as well as direct requests to public institutions in the state of Maranhão. Due to the lack of updated data, different reference years were used. The period variation of the collected data was between 2010 (last IBGE census) and the year 2022. The collected data was organized into an Excel spreadsheet and used to create a synthetic indicator, so comparisons could be possible.

3.4 Construction of the Sustainability Index (IS)

The method for creating the Sustainability Index (SI) followed the principles proposed by Waquil et al. (2010). This method changes the indicators into index allowing the comparison of variables from different units, transformed into dimensionless values. Thus, a scale of values was used to measure the performance of the municipality towards the upper limit (target value), which corresponds, respectively, to 0 (minimum performance at the target value) and 100 (maximum performance at the target value).

The upper limit (target value) and the lower limit were established according to two criteria, recommended by the methodology of the Sustainable Development Solutions Network (SDSN), created in 2012 by the UN, with some adaptations.

For some indicators, the upper limit (target value) was used for universal access (100) or total deprivation (0), observing the influence (negative/positive) of the indicator. For example: The indicator Unemployment rate in the city (%) has a negative influence, because the higher its value, the closer it is to a negative situation. In this case, the upper limit used must be considered zero.

For the other indicators, the municipality that presented the best performance was used as the upper limit (target value) and for the lower limit, the municipality that presented the worst performance in the indicator.

The formula used to calculate the index has a result in percentage:

$$x = \frac{obs - mín}{máx - mín}\ x\ 100$$

Where:
x = standardized indicator (for each axis/municipality)
obs = indicator value in each municipality.
min = lower limit
max = upper limit

This formula was applied to each indicator collected, then it was calculated the arithmetic mean to obtain the index by thematic axis. After that, it was possible to calculate the General Sustainability Index (IS) for each municipality, through the average of the results obtained in each axis. To grade the level of sustainability of the municipalities, the classification suggested by Martins and Cândido (2008) was used: B - Bad (0 – 25); Re - Regular (25.1 – 50); A - Acceptable (50.1 – 75); and E - Excellent (75.1 – 100).

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Finally, for a better visualization and analysis of the results, a ranking was created with the indexes of the municipalities. In this case, a color scale was used to represent the variation of the final values: red for bad situation (B); orange for regular (Re); yellow for acceptable situation (A) and green for excellent situation (E).

4 OUTCOMES

This segment aims to present the outcomes from the application of the methodology in order to elaborate the sustainability index (SI) of the municipalities of Ilha do Maranhão. Regarding the characterization of the Island of Maranhão, it was verified that the municipalities of São Luís, São José de Ribamar, Paço do Lumiar and Raposa have a relation that is characterized by the establishment of an urban network, sharing services and job offers, daily commuting and the expansion of the urban fabric. Such notes become relevant in this analysis once the adopted indicators (ABNT ISO 37120:2017) consider the use of variables that measure urban services and the quality of life of the population - fundamental aspects for the construction of sustainable cities.

The application of the indicators was considered partial, once it was not possible to obtain all the recommended data, leaving gaps in part of the thematic axes. The lack of data for calculating the indicators is related to the struggles presented in data collection. Such difficulties refer to the lack of organization, control and means of disclosing data by public agencies. Another relevant point at this stage of the research considers the lag of part of the data used, specifically those collected in the IBGE Census, whose research dates from the year 2010.

The creation of a synthetic index allowed the crossing of the variables of each thematic axis. This way, it was possible to obtain an index for each axis, which values were measured in percentage (%) and categorized by colors that represent the sustainability condition of each axis by municipality, as shown in Table 3.

Table 3 – Synthetic index by thematic axis (%)

SYNTHETIC INDEX BY THEMATIC AXIS (%)				
AXIS	**SÃO LUIS**	**RAPOSA**	**PAÇO DO LUMIAR**	**SJ RIBAMAR**
ECONOMY	86,49	75,56	84,73	83,77
EDUCATION	70,48	64,99	83,08	73,63
ENERGY	71,59	49,19	71,92	95,59
ENVIRONMENT	0,00	27,92	27,71	51,26
FINANCE	100,00	0,00	0,00	28,84
FIRE RESPONSE AND EMERGENCIES	100,00	0,00	69,28	5,76
GOVERNANCE	54,33	45,34	96,10	79,73
HEALTH	75,00	26,47	46,77	52,23
SECURITY	72,03	79,39	26,75	0,00
HOUSING	77,05	75,65	87,80	55,24
SOLID WASTE	66,76	DNI	52,10	33,33
TELECOMMUNICATIONS AND INNOVATION	100,00	25,69	5,08	24,29

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TRANSPORT	0,00	0,15	0,09	0,10
URBAN PLANNING,	100,00	45,23	0,00	27,79
SEWAGE	39,76	DNI	50,77	69,88
WATER AND SANITATION	75,57	56,32	72,74	69,16

LEGEND COLOR SCALE	BAD	REGULAR	ACCEPTABLE	EXCELLENT
DNI - Data not informed	**0 – 25%**	**25,1 – 50%**	**50,1 -75%**	**75,1 – 100%**

Source: Prepared by the author (2022).

After calculating the synthetic index by thematic axis, it was possible to estimate the general index of the level of sustainability of the municipalities of Ilha do Maranhão. The results obtained were organized as a ranking (Table 4), which indicates the values (IS) reached for each municipality and the categorization regarding its sustainability condition.

Table 4 - Ranking of municipalities - Sustainability Index (IS)

RANKING OF MUNICIPALITIES - SUSTAINABILITY INDEX (IS)			
SÃO LUIS (1º)	PAÇO DO LUMIAR (2º)	SJ RIBAMAR (3º)	RAPOSA (4º)
66,84	51,28	48,54	38,13
BETTER SITUATION			WORST SITUATION
ACCEPTABLE		REGULAR	

Source: Prepared by the author (2022).

The results reveal that the municipality of São Luís had the highest rate among the four municipalities, reaching first place in the ranking with a rate of 66.84%, fitting into the acceptable category (A). Right after the capital, the municipality of Paço do Lumiar reached 51.80% which was also considered as an acceptable situation (A). The municipalities of São José de Ribamar (48.34%) and Raposa (38.89%) reached results considered regular (Re).

5 FINAL CONSIDERATIONS

Given the importance of working with management based on data and indicators, it is observed that efforts are ongoing to develop systems of indicators that are verifiable, measurable, comparable and appropriate to the context of Brazilian cities. ISO 37120, as a universal standard, presents in its scope a diverse range of indicators that transit through 17 thematic axes related to the principles of sustainable cities and SDG 11. The version modified by ABNT showed that in general its indicators can be measured and applied to Brazilian cities, regardless of size and population.

Such conclusions were based on the use of these indicators in the construction of the sustainability index (IS) for the municipalities of Ilha do Maranhão. The analysis of the results revealed that the sustainability condition of the municipalities ranges between acceptable (São Luís and Paço do Lumiar) and regular (São José de Ribamar and Raposa), which points out to the need of investigating the critical points that led to such results. That situation can be interpreted as non-compliance with the goals established at a local level for the 2030 Agenda. It is important

to consider in this analysis that the results depend on which indicators were used, which situation was investigated and the time frame of data collection.

Thus, we can conclude that sustainability indicators and indices should be understood as tools to identify the situation of a municipality regarding its progress towards sustainable development. The use of indicators is essential for municipal public management, in order to provide the municipality with useful data and information for defining clear and achievable objectives and targets for meeting the goals established by the 2030 Agenda.

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