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ORIGINAL RESEARCH ARTICLE

Urban indicators of Peru's atoll metropolitan area and its impact on urban sustainable development

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ABSTRACT

The purpose of the study is to determine the impact of urban indicators on the sustainable development of the Atoll metropolis in the Junín region, Peru, including the impact of its specific urban composition and territorial allocation, natural resource management, social cohesion, and economic development on urban sustainable development. Three methods were used: the first was the evolution map indicator and census information system the second was the method record of testing the integrated urban indicator system of urban planning from 1961 to 2011, and the third was the method of estimating the sustainable development level of the territory, according to the 2008 biography prepared by the Inter American Institute of Agricultural Cooperation. The following results were achieved: The bulk density of 115.87 inhab/ha in 1961 decreased steadily in 2011, reaching 93.67 inhab/ha. The comparative urban planning from 1961 to 2011 decreased from 14 indicators obtained to only one indicator applicable. It was noted that 13 indicators were not applicable due to method defects, and monitoring was not allowed due to a lack of reliability. Finally, the biography showed the trend toward urban stability. The results show that the urban indicators are practical, which shows the degree of impact on the current and predictable situation of urban human settlements. Although this situation has achieved vegetation growth in an inert and spontaneous way, it has led to an improvement in sustainability in the medium term.

Keywords: metropolis; sustainable development; urban indicators; urban sustainability

1. Introduction

Mantaro Valley is a special ecosystem in the context of Peru's environment, with highly productive soil, a perennially small watershed, and a beautiful natural landscape. Martinez's study on the environmental vulnerability of Mantaro Valley[1] pointed out that the growth and dynamics of cities lead to the vulnerability of Mantaro Valley, including environmental imbalance. If the allowable impact limit is exceeded, the conflict between cities and territories will be generated through the disorderly occupation of agricultural land in urban settlements, uncontrolled exploitation of natural resources, excessive water use, air, water, and soil environmental pollution, and lost scenery and customs. Therefore, it is necessary to understand the reasons for this process, including inappropriate decisions and processes made by rulers and people without any con-

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trol or monitoring system. Therefore, it is necessary to establish an urban indicator system.

Integrating the global trend of urban management indicators is a challenge for developing countries, especially for metropolises with populations ranging from 500,000 to 99.9999[2], such as atolls, where there is no precedent, which will enable them to have a database, statistical control processes, indicators to design urban development policies, strategies, actions, and projects.

Since the urban management of Peru's national system and the city of Huancayo is not based on systematic urban indicators, this leads to insufficient decision-making about urban development projects. From the 17 urban plans formulated from 1943 to 2006–2011, it can be seen that these plans have been surpassed by reality and failed to achieve the proposed objectives, resulting in spontaneous urban growth, disconnection of physical urban spatial structure from the center to the periphery, and occupation of urban land. In the absence of adequate basic services and equipment, the housing, construction, and health departments did not implement urban observatories or set urban indicators, leading to people's wrong understanding of the quality of urban life.

Since Agenda 21[3], the formulation and application of sustainable urban development indicators in Latin America have been applicable to Brazil, Mexico, Argentina, Colombia, Chile, and other countries.

In our case, it has been provided in Supreme Decree No. 022-2016-VIVIENDA prepared by the Ministry of Housing Construction and Sanitation[4], Article 77 of which stipulates that local governments implement local urban observatories according to the evaluation and monitoring indicators specified in their respective plans to evaluate and monitor technical schemes, product data management schemes, product data units, and EU. Therefore, there is an urgent need to start implementing this management and planning tool and integrate it into the measurement system of urban observatories to promote sustainable development.

It is possible for local governments to start this process when this problem still exists. The problem described by dividing the urban background into three dimensions or factors is explained by the urban indicators shown in **Figure 1**.

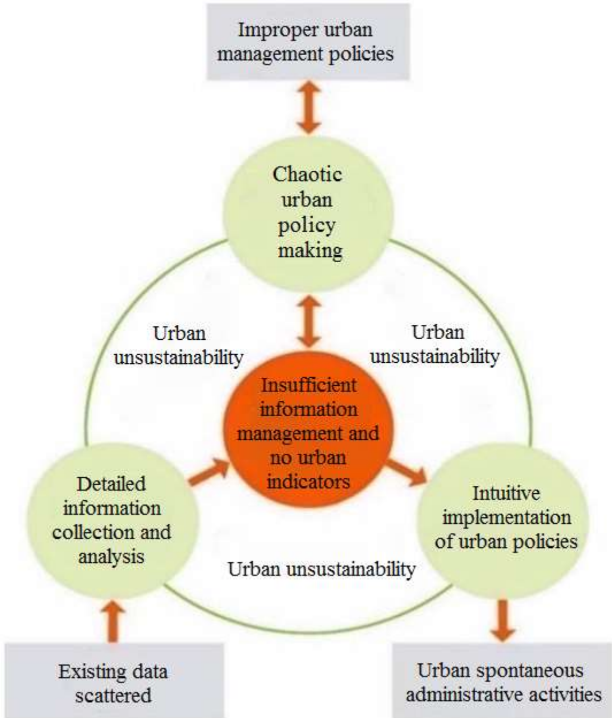


Figure 1. Solve the problem of urban unsustainability. Based on[5], and its own sufficiency.

Figure 1 depicts the state of world environmental management in 1997. By maintaining the described state, it becomes potential in our environment. The scattered existing data not only leads to the disconnection of information collection and analysis but also leads to the poor management of urban information, resulting in spontaneous urban administrative activities and disconnected urban decision-making. This leads to the question. Through the application of urban indicators, the main objective is to determine how urban indicators affect the sustainable urban development of Peru's Atoll metropolis.

It takes into account the process followed by research to achieve this goal, such as the analysis of urban development plans without validation indicators, which are strictly constructed based on national census data confirmed by environmental mapping research.

2. Theoretical framework

The theoretical framework developed as a follow-up stage for research issues and objectives allows the review of the background, theoretical basis, and conceptual definition of terms. Barnett & Parnell[6] put forward the importance of cities and sustainable urban development, the necessity of institutionalization in their research work, and the post-2015 agenda. It believes that advocacy for activism and how to use urban indicators to monitor and evaluate the process of urban transformation are relevant.

Kitchin[7] assessed the draft initiatives and indicators developed and adopted by the city and pointed out the possibility of manipulating vested interests and changing unrecognized methodological and technical issues. This proves the urgent need to study it, that is, to use and overcome the childishness of instrumental rationality.

In Turku's research work[8], it reflects on measurement and methods of sustainability, and includes the same process followed by the research, so as to draw the conclusion that indicators are the most influential measurement tool among all indicators. Finally, it summarizes its potential applicability in local government.

The theoretical framework enables us to design the methodological design of research, that is, the moment when we establish, analyze, and collect information, which provides us with a deep understanding of the theory that gives research significance.

Application Guide: The comprehensive urban index system, urban environment observation station (UEOS), developed by UNHABITAT/ROLAC[9], is the system I rely on in this study, because it has been in place and is being fully implemented and improved. This integrated system involves partner cities: Calvia (Spain), Malaga (Spain), Treviso Province (Italy), Rosario (Argentina), Montevideo (Uruguay), Belo Horizonte (Brazil), Atlantic Regional Autonomous Corporation (Colombia), and Vina Del Mar (Chile). All indicators and indexes are shown in **Figure 2**.

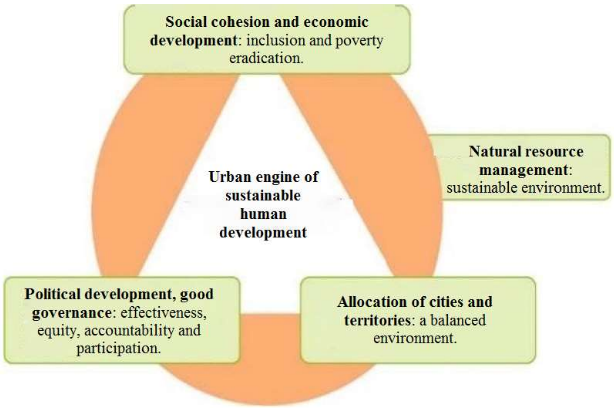


Figure 2. The dimension of sustainable development, Omaha. Based on[9]. Application Guide: Urban comprehensive index system, urban environment observation station (UEOS), page 6. Malaga City Council.

According to the data from the Urban Environment Observatory (UEOS), **Figure 2** shows the four main dimensions of the urban indicators of the system. The system will be used as information for the evaluation of urban sustainable development in the Atoll metropolitan area.

Manher and Bunge's development theory[10] has been adopted as the overall framework, including sustainable development and its project indicators. We believe that a period (or stage) in the life history of an organism is a development process, whether constitutive or structural, only when it is accompanied by the emergence or inundation of at least one general attribute (or quality). In addition, we stipulate that the quality change discussed must be an internal event or process, that is, an event or process involving some organizational activities or functions.

Represents a set of generic properties of a biological system B at a certain time t. In addition, let us call s state B in time t and s state t in time t, where t' > t. Therefore, the event (or process) "s, s" is the development event (or process) of B, provided that:

(i) "S, s" › not (directly) caused any environmental factors.

(ii) P(b, t') ≠ P(b, t).

We regard the atoll city as a biological system. In 48 years (starting from the 1961 census), it has changed its general qualitative nature in structure and form.

Using the concept of sustainability proposed by Gallopin[11], we can define it as:

(iii) $V(SU_{t+1}) \geq V(SU_t)$

where V is the evaluation function of the urban system state or state (*SU*) (that is, when the "net value" of the system or its products is not necessarily expressed in economic terms, the system is sustainable.

3. Methodology

There are three methods. The first is environmental mapping and its evolution to the current situation of territory and population; the second is to compare the urban indicators of urban planning management and their possibility of use; the third, establish the index system of urban application biography.

In the first environmental mapping method, McHarg[12] was used as a methodological reference based on data provided by official sources of the National Institute of Statistics and Informatics, the National Aeronautical Photography Administration (SAN), the National Geographic Institute (IGN), and the OIKONOS private satellite imaging company. It is processed by the CAD-GIS system. In order to quickly and comprehensively understand the territorial situation of Peru's atoll metropolis, we mapped the historical evolution of Peru's atoll metropolis from 1954 to 2016 and calculated the density in different periods analyzed.

In the second method, the urban indicators in the urban planning of the atoll metropolis are compared through descriptive memory. Therefore, the archives are searched in local, regional, national and private institutions to obtain the indicators processed in the urban planning of Atoll Metropolis: explanatory memory using Ing. Oswaldo Raez Patiño and the following five urban plans:

(1) 1960 atoll control plan, developed by the National Bureau of Planning and Urban Planning, ONPU[13].

(2) The overall plan of Atoll City was formulated by the Atoll Provincial Council and the Ministry of Housing and Construction from 1976 to 1985[14].

(3) The overall plan of Atoll City in 1991 was formulated by the provincial government of Atoll[15].

(4) 1996–2005 overall plan of Atoll City, prepared by Atoll City and National Institute of Urban Development, INADUR[16].

(5) The 2006–2011 urban development plan of Atoll City was formulated by the provincial government of Atoll[17], which is currently effective.

(6) The 2017–2037 metropolitan development plan[18] formulated by the atoll provincial government was finally approved through consultation and was not included in the study.

Figure 3 outlines the relationship between the indicators obtained in the atoll metropolitan urban plan and the urban indicator system[9], through the preparation of the methodology table of the urban comprehensive indicator system of UN Habitat.

In the third method of estimating the sustainable development level of the territory used to generate the territorial sustainable development index, there are two important references in cooperation with Biograma developed by Sepúlveda[19] of the Inter American Institute of Agricultural Cooperation (IICA): Method table of comprehensive urban index system of Malaga urban environment observation station (UEOS). It was supplemented by PGU-ALC, or habitat in 2001, known as Istanbul +5 city index, which was supplemented in 2004.

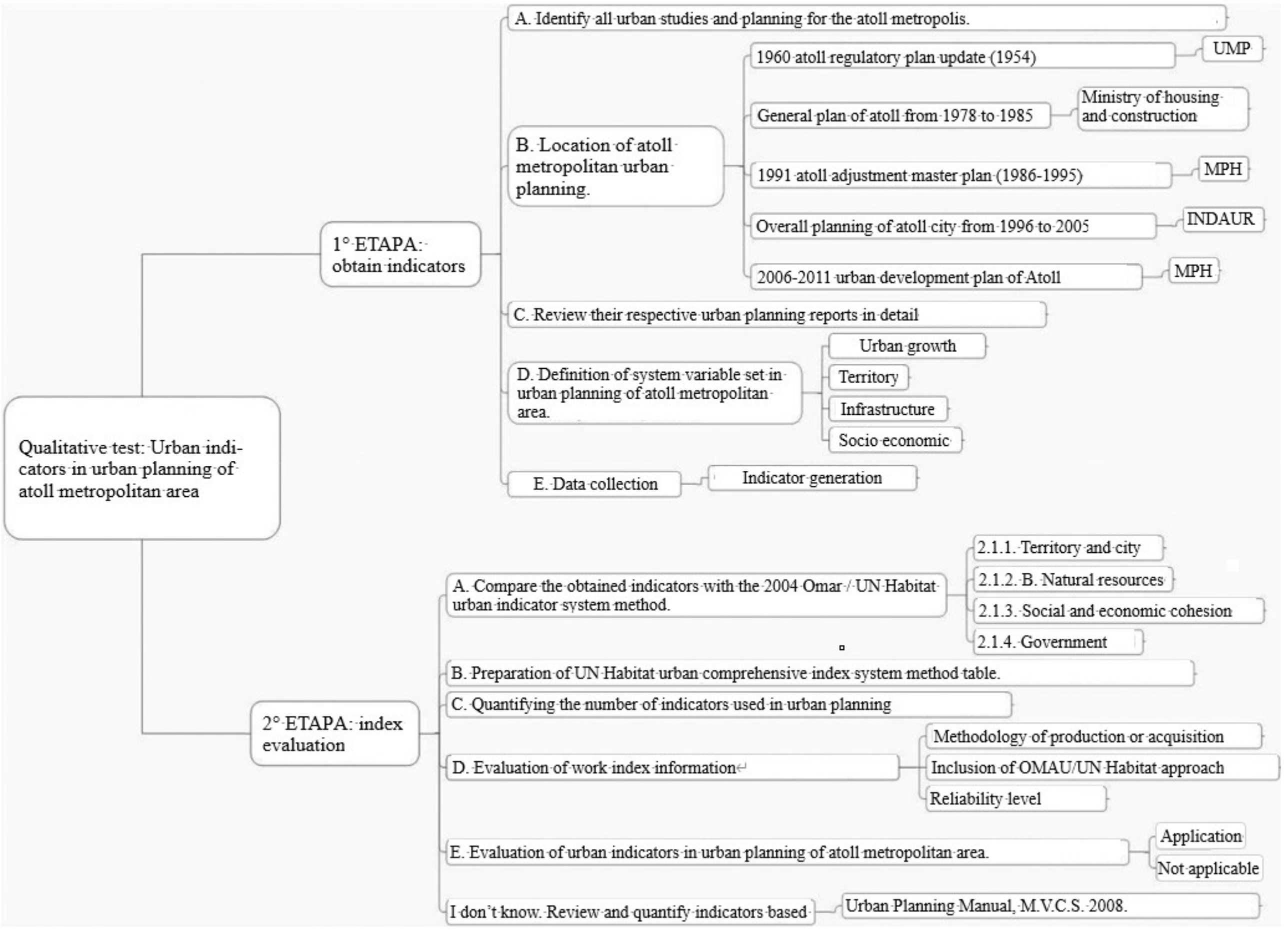


Figure 3. Method and process: Comparison of urban indicators in urban planning of Peru's Atoll metropolis.

Table 1. Indicators, variables and dimensions for sustainable development analysis

I. Allocation of cities and territories	II. Natural resource management	Chapter three. Social cohesion and economic development
TC 1.1.0 population growth	NR 2.1.0 water price, new sole/100 litres of water	Se 3.1.1 housing tenure: self-owned housing
TC 1.2.0 population density	NR 2.2.0 power consumption. Per capita consumption	Se 3.1.2 housing tenure: rental housing
		Se 3.1.3 housing tenure: other housing
		Se 3.2.0 access to sanitation
		Se 3.3.0 access to drinking water
TC 1.3.0 average family size	NR 2.3.1 integrated solid waste management: %A family with a harvest	Se 3.4.1 connectivity to information and communication technology: fixed line telephone services
		Se 3.4.2 connectivity to information and communication technology: computers
TC 1.4.0 family training fee	NR 2.3.2 integrated solid waste management: quantity per week	Se 3.5.0 power service coverage
TC 1.5.0 urban population/total population	NR 2.3.3 integrated solid waste management: Sanitary Landfill	Se 3.6.0 total unemployment rate
		Se 3.7.1 literacy rate
		Se 3.7.2 literacy gap by sex

The final version of Biograma in 2008 has been implemented and regularly revised for more than a decade, covering topics related to spatial methods and suitable for urban areas. This study identified four city analysis units, as follows: Huancayo, Chilca, Tambo, and the metropolis of Huancayo are the first three units. According to the 10-year forecasts of 1961, 1971, 1981, 1991, 2001, and 2011, the 1961 census[20] was submitted by the National Bureau of Statistics and Census, the 1972 census[21] was submitted by the Bureau of Census, sampling and special survey, the 1981 census[22] was submitted by the National Bureau of Statistics and the 1993 census[23] was submitted by the National Institute of Statistics and Informatics, and the last census of 2007 was submitted by the National Institute of Statistics and informatics of Peru[24]. The dimensions or components of the system fully reflect the status of the analysis unit. Therefore, the following dimensions are adopted: the allocation of cities and territories, the management of natural resources, and ultimately social cohesion and economic development. The Department of Biology uses five colors to describe the sustainable development of the analysis unit.

Table 1 shows the indicators, variables, and dimensions used for sustainable development analysis in the 2008 final biomass scale.

The population consists of 8 major cities in the macroregion excluding Lima and Vancayo, as shown in **Figure 4** and the sample is shown in **Figure 5**.

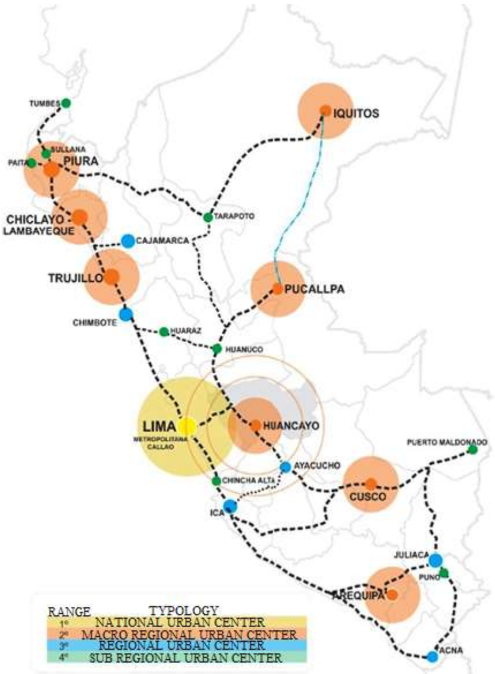


Figure 4. Peruvian national population center system: System and subsystem, based on the Ministry of housing construction and health[4].

Environmental mapping results

In **Figure 6**: The historical evolution of Peru's atoll metropolis from 1954 to 2016, **Figure 7**: Urban density of regular sustainability analysis (Biograma 1961, 1971, 1981, 1991, 2001 and 2011) shows the population growth and decline of urban areas and atoll metropolises. According to the following characteristics obtained from the data prediction, the area in 1961 was 553 hectares, the population was 64,153, and the density was 115 hectares/ha, and the area in 2011 was 3676 hectares, with 344,410 people and a density of 93 HAB/ha. As a result, in the above years, the area increased six times, the population increased 5.36 times, and the density decreased 0.8 times.

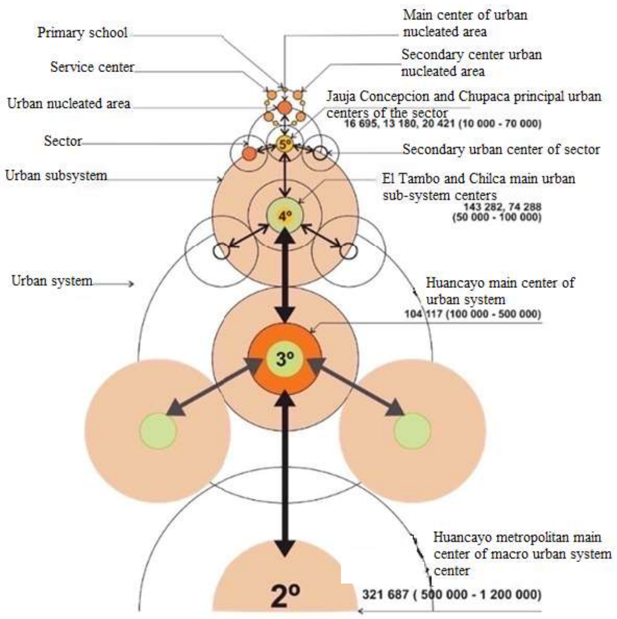


Figure 5. Sample from the Peruvian macro system center. Adapt to the national population center system: Macro control center of the Ministry of housing construction and health[4].

Similarly, El Tambo has a larger urban area than Huancayo and Chilca.

Unlike the continuous increase in population and urban area over time, population density is declining. At the metropolitan level, there is a trend towards expanding cities, noting that the urban density provisions in different urban development plans, including the current plans from 2006 to 2011, are inconsistent.

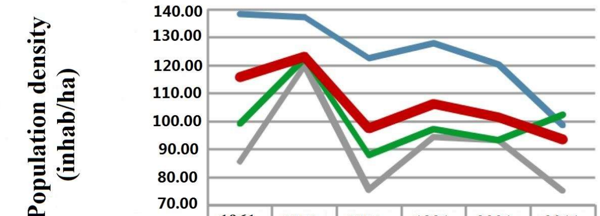
The index system is the product of revising the following contents:

(a) Descriptive Memoirs of Urban Planning of Vancayo City.

(b) Ministry of Housing, Construction and Health, Handbook of Urban Development Plan 2008, Inicam.

(c) Omar UN Habitat urban indicator system.

The comparison table shows that only 9 indicators of the planning methods are qualified, and only 1 of them is applicable to the comparison table in **Figure 2**. The remaining 13 indicators reported methodological deficiencies in obtaining these indicators according to the UN Habitat methodology and unreliable data. Therefore, it is necessary to establish new indicators based on the census, as shown in **Figure 10**.



	1961	1971	1981	1991	2001	2011
Huancayo	138.49	137.34	122.64	127.93	120.29	98.60
Chilca	85.51	120.00	75.45	94.34	93.27	75.15
El Tambo	99.09	122.55	87.87	97.33	93.39	102.26
Huancayo Metropolitano	115.87	123.14	97.55	106.26	101.34	93.67

Figure 7. Urban density for periodic sustainability analysis censuses and aerial photography in 1961, 1971, 1981, 1991, 2001, and 2011. Comparison results of urban indicators in urban planning of Atoll metropolitan area.

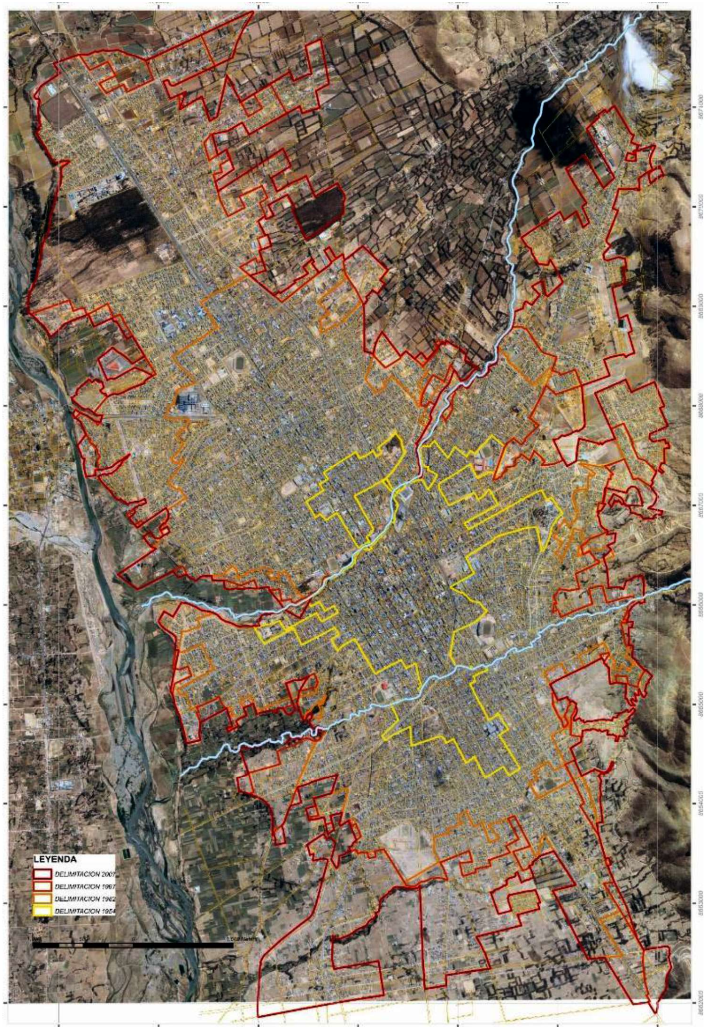


Figure 6. According to the historical evolution of Peru's atoll metropolis from 1954 to 2016, satellite images and aerial photography determine the urban perimeter according to the perimeter determined in the corresponding urban planning.

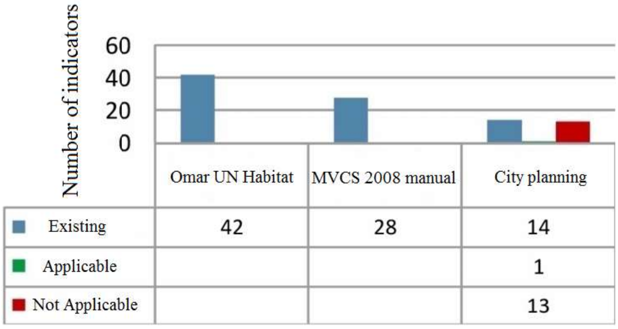


Figure 8. Index evaluation of atoll urban planning.

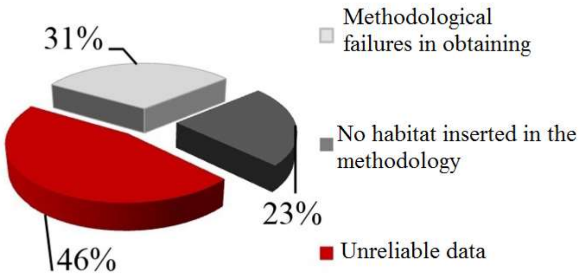


Figure 9. The reason why the treated index is not applicable.

Table 2. Comparison of urban planning indicators, MVCS manual and UEOS-2006, UN Habitat, 2004

Hurbanos Huancayo plan (a)		Manuel MVCS 2018 (b)		Omaha, a habitat (c)	
Urban growth	Population Surface area Population density Urban expansion land demand	Demographic	Population growth Population density Urban population by sex Spatial distribution of urban population	Territory and city	Population growth Population density Land use Public space transportation
Territory	Land use Architectural features River pollution (Introduction)	Physical environment	Land use Road and transportation Urban equipment Public service B. Natural resources Hazardous area	B. Natural resources	Air quality Water quality Per capita water consumption Destination solid waste Vegetation coverage Bio-diversity
Substructure	Urban equipment Road and transportation Service	Social	Access to basic services Poor Obtain employment Educational level Healthy Socio-economic level Human development	Social cohesion and economic development	Housing Education Healthy Service Employment and economic development Poor Human development
Socioeconomic	Demographics Housing Site instability Economic activity Formal trade	Economical	Outputs by Sector Economic activity Informal Spatial distribution of economic activities	Government	Government efficiency Local government revenue Gender equality Citizen participation Citizens association

In order to adapt the indicators to a common scale, a relativistic function was used, which was based on the calculation method of the human development index proposed by UNDP. For the case where the indicators are positively correlated, the following Equation (1) is used:

$$F(x) = \frac{x = m}{M - m} \quad (1)$$

If there is a reverse relationship between indicators, the above formula is modified to maintain its characteristics:

$$f(x) = \frac{x - m}{m - M} \quad (2)$$

In these formulas:

x = the corresponding value of the variable or index of a given analysis unit in a given time period.

m = is the minimum value of the variable in a given period.

M = highest level in a given period.

Using these formulas, each indicator has a separate index, ranging from 0 to 1. For both cases (when the indicator shows a positive or negative relationship), a value of 1 indicates the better case and a value of 0 indicates the worst case. The above formula relativizes all indicators, resulting in a new comparative analysis set.

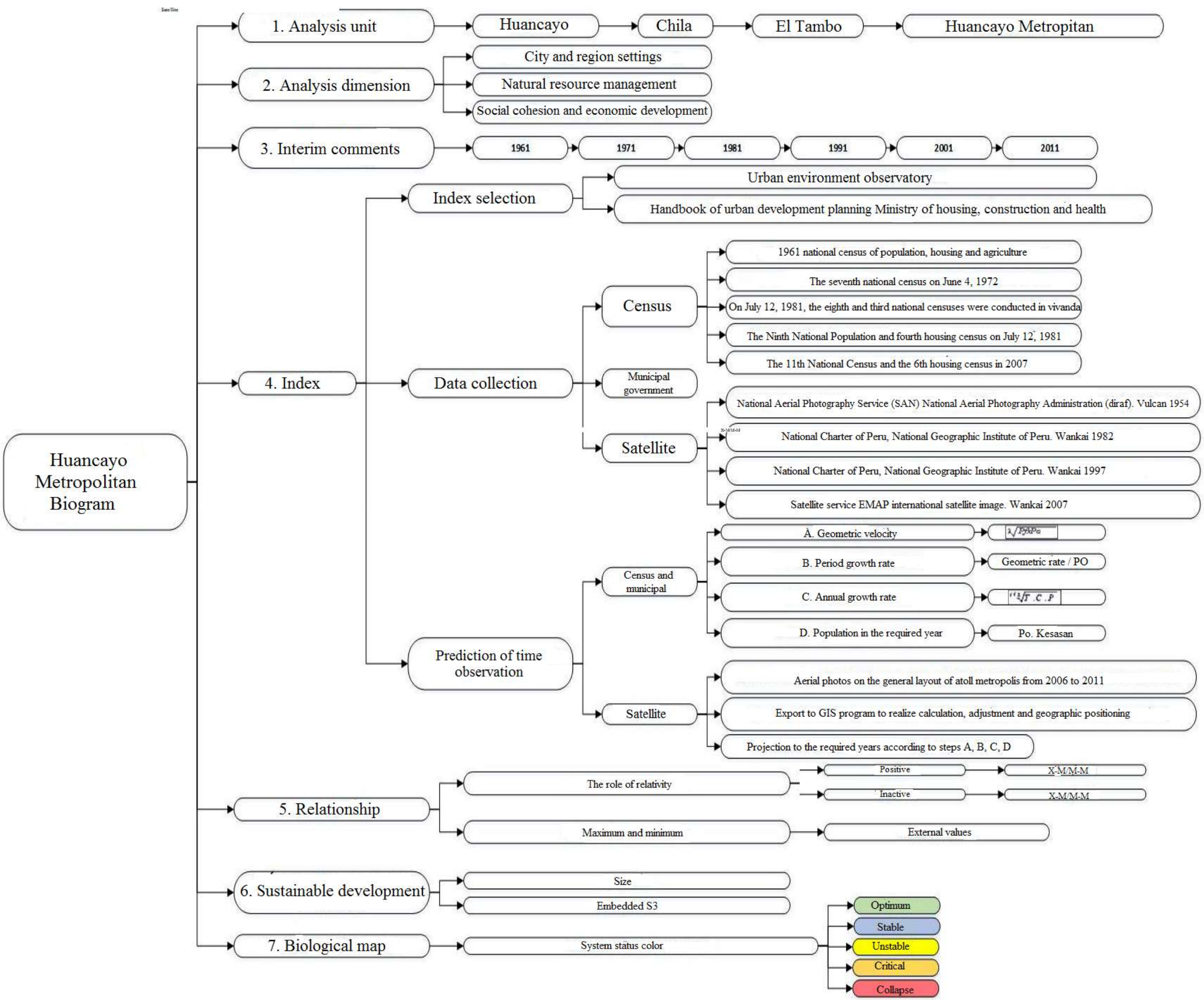


Figure 10. Procedures for assessing the level of sustainable development in the territory, biograma 2008.

Maximum and minimum levels

As shown in Equations (1) and (2), in order to make the indicators comparable, it is necessary to set a maximum value and a minimum value for each type of data to be analyzed. Therefore, the most direct choice is to simply use the maximum and minimum values of the observed values. This process allows an indicator to be obtained that reflects the position relative to the analyzed time period. Therefore, the indicator will display 1 when it reaches the maximum observation level and 0 when its lowest level appears.

The procedure for finding the maximum and minimum values is determined based on the observed values.

Extreme value

The determination of an extreme value can be realized by statistical analysis independent of the data series. In any case, this establishes a limit value, which is considered to be generated from it. Similarly, you can set only one maximum value, allow the minimum value to be the observed value, or set the minimum value without changing the maximum observed value to the maximum value. If these values are not considered, the sequence data will remain within the normal fluctuation range. Fluctuation limits also work when dealing with small data sets. In the absence of a long time series showing the normal behavior of the research unit, the process of establishing extreme values allows the comparison mode of the collected data.

In calculating the sustainability index, an equation (Equation (3)) is used, which first calculates the weighted average of the indicators of each dimension previously relativized. The index calculation formula for each dimension is as follows:

$$S_D = \frac{1}{n_D}\sum \frac{n_D}{i=1} I_i^D \qquad (3)$$

Among them, it is the indicator of dimension *D* and is understood as the indicator of dimension *D*. Therefore, it is the average value of dimension indicators. These indicators were standardized before, so the value between 0 and 1 is taken.

Then add the indexes of all dimensions to obtain the integrated index. The aggregation is always done by weighting each dimension by an important percentage (△ d). The equation for calculating the comprehensive sustainability index is (Equation 4):

$$S^3 = \sum \frac{M}{1}\frac{\beta_D}{100} S_D \qquad (4)$$

The importance percentage of the atoll metropolis is as follows: urban and territorial allocation is 0.35, natural resource management is 0.30, and social cohesion and economic development are 0.30.

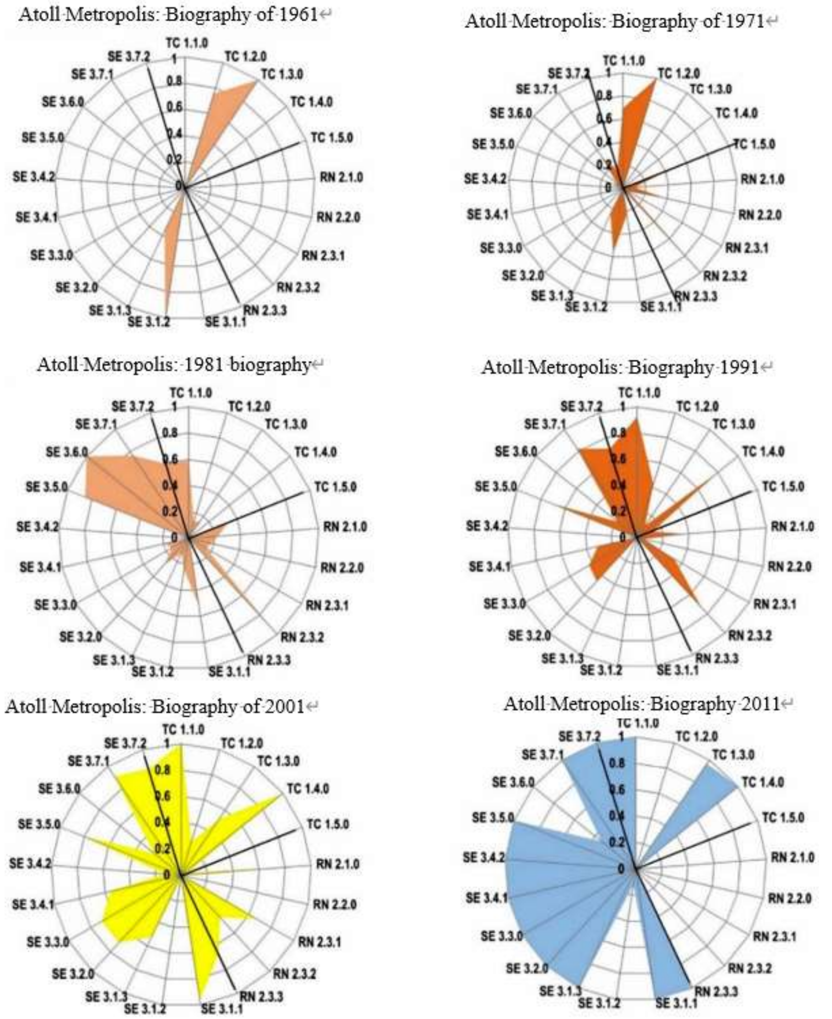


Figure 11. Summarize the change trend of comprehensive sustainable development index S3 of atoll metropolitan area in 50 years, which changes every 10 years. Application based on biography 2008 method.

Atoll metropolitan area:

Figure 11 shows the ten-year comprehensive sustainable development index of the Atoll metropolis from 1961 to 2011. The results are as follows:

1961, key systems. (0.37)

Key systems, 1971. (0.30), growth slowed

1981, critical systems. (0.32)

In 1991, the system was unstable. (0.40)

In 2001, the system was unstable. (0.50)

In 2011, the system was stable. (0.69), with greater growth.

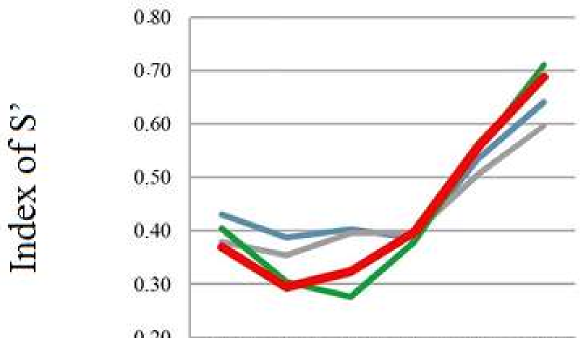
Research findings:

(1) Taking the Atoll metropolitan area as an example, this paper diagnoses the urban planning and urban management systems as a way to predict the urban situation in the national context.

(2) Preliminary evaluation of sustainable development of Atoll metropolitan area

(3) The UN Habitat Agenda has an urban Observatory program, which registers 353 cities in the world and sets urban indicators; 39 cities in Latin America and the Caribbean are led by Brazil, 15 cities, 7 cities in Mexico, and no city registration in Peru. Therefore, it is necessary to create the necessity of using urban indicators as urban management tools.

4. Discussion and conclusion



	1961	1971	1981	1991	2001	2011
Huancayo	0.43	0.39	0.40	0.39	0.64	0.54
Chilca	0.38	0.35	0.40	0.40	0.51	0.60
El Tambo	0.40	0.30	0.28	0.38	0.56	0.71
Huancayo Metrop	0.37	0.30	0.32	0.40	0.56	0.69

Figure 12. The sample of urban areas in El Tambo district has progressed smoothly during the 50-year evaluation period.

From the results obtained and shown in **Figure 12**, it is consistent with the adopted sustainable development theory. As a biological system, the general qualitative nature of the structure and form of the Atoll metropolis has changed in the course of 48 years (starting from the 1961 census). In addition, let's call its status (T) according to the development index 0.37 (b) in 1961 and (t') according to the development index 0.69 (b) in 2011, where t' > t. Therefore, the "s, s" process is the development process of B.

The UEOS comprehensive system consists of four dimensions. The first three dimensions are developed according to methodology, and the governance dimension is pending due to the lack of information within the research scope. For each dimension, it has the following results: The overall structural dimension of the city and territory shows an unstable trend, which is maintained by the urban area of El Tambo, which is unstable due to the continuous decline of Huancayo and Chilca and the rise of the index. In general, the level of natural resource management is stable and shows the same behavior as Huankayo, Chilka, and Tambo. The results show that the social cohesion and economic development of each component of the Atoll metropolitan area tend to be the best on the whole.

Regression analysis and correlation analysis show that the overall impact of urban indicators in the Atoll metropolitan area on urban sustainable development reaches a 95% confidence level. For the comparison of specific assumptions, the Pearson correlation model is used to determine the significance of various dimensions and dependent variables on urban sustainable development. Urban natural resource management indicators affect the urban sustainable development of the atoll metropolitan area and urban social cohesion and economic development indicators also affect the urban sustainable development of the atoll metropolitan area, which is different from the urban form and regional indicators that do not affect the urban sustainable development of Atoll metropolitan area. The quality and quantity of public space in the atoll metropolitan area do not meet the established minimum standards, reflecting the non-impact of urban and territorial allocation dimensions, including public space indicators.

It is believed that there are few effective indicators for urban planning from 1960 to 2011, and the structural level of cities and territories is a favorable indicator to evaluate the implementation of urban planning. Therefore, there is an urgent need to use urban indicators to operate cities in order to monitor the sustainable development of cities, so that sustainable cities do not become a simple political discourse.

5. Proposal

The national system led by the Ministry of Housing should be urgently integrated into the Latin American urban observatory, otherwise, it should implement its own system through the urban indicator urban observatory at the national, regional, and local levels. Assess the sustainable development of urban areas in order to continuously develop and improve urban management in all aspects of the city.

Conflict of interest

The authors declare no conflict of interest.

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