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ITU-T Y Suppl. 78 (09/2023)

SERIES Y: Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

Use cases on implemented or evaluated smart sustainable city solutions based on ITU-T Y.4900 Recommendations series

ITU-T Y-SERIES RECOMMENDATIONS

Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

GLOBAL INFORMATION INFRASTRUCTURE	Y.100-Y.999
General	Y.100-Y.199
Services, applications and middleware	Y.200-Y.299
Network aspects	Y.300-Y.399
Interfaces and protocols	Y.400-Y.499
Numbering, addressing and naming	Y.500-Y.599
Operation, administration and maintenance	Y.600-Y.699
Security	Y.700-Y.799
Performances	Y.800-Y.899
INTERNET PROTOCOL ASPECTS	Y.1000-Y.1999
General	Y.1000-Y.1099
Services and applications	Y.1100-Y.1199
Architecture, access, network capabilities and resource management	Y.1200-Y.1299
Transport	Y.1300-Y.1399
Interworking	Y.1400-Y.1499
Quality of service and network performance	Y.1500-Y.1599
Signalling	Y.1600-Y.1699
Operation, administration and maintenance	Y.1700-Y.1799
Charging	Y.1800-Y.1899
IPTV over NGN	Y.1900-Y.1999
NEXT GENERATION NETWORKS	Y.2000-Y.2999
Frameworks and functional architecture models	Y.2000-Y.2099
Quality of Service and performance	Y.2100-Y.2199
Service aspects: Service capabilities and service architecture	Y.2200-Y.2249
Service aspects: Interoperability of services and networks in NGN	Y.2250-Y.2299
Enhancements to NGN	Y.2300-Y.2399
Network management	Y.2400-Y.2499
Computing power networks	Y.2500-Y.2599
Packet-based Networks	Y.2600-Y.2699
Security	Y.2700-Y.2799
Generalized mobility	Y.2800-Y.2899
Carrier grade open environment	Y.2900-Y.2999
FUTURE NETWORKS	Y.3000-Y.3499
CLOUD COMPUTING	Y.3500-Y.3599
BIG DATA	Y.3600-Y.3799
QUANTUM KEY DISTRIBUTION NETWORKS	Y.3800-Y.3999
INTERNET OF THINGS AND SMART CITIES AND COMMUNITIES	Y.4000-Y.4999
General	Y.4000-Y.4049
Definitions and terminologies	Y.4050-Y.4099
Requirements and use cases	Y.4100-Y.4249
Infrastructure, connectivity and networks	Y.4250-Y.4399
Frameworks, architectures and protocols	Y.4400-Y.4549
Services, applications, computation and data processing	Y.4550-Y.4699
Management, control and performance	Y.4700-Y.4799
Identification and security	Y.4800-Y.4899
Evaluation and assessment	Y.4900-Y.4999

For further details, please refer to the list of ITU-T Recommendations.

Supplement 78 to ITU-T Y-series Recommendations

Use cases on implemented or evaluated smart sustainable city solutions based on ITU-T Y.4900 Recommendations series

Summary

Supplement 78 to ITU-T Y-series Recommendations aims to collect use cases from ITU members that have implemented or evaluated smart sustainable cities (SSCs) based on the ITU-T Y.4900 Recommendations series.

The aim of this Supplement is to provide information and identify challenges and opportunities on the implementation and evaluation of SSC solutions, based on the ITU-T Y.4900 Recommendations series, across a wide spectrum of real scenarios (such as varied infrastructure maturity, city size, financial conditions, etc.).

It is expected that the use cases collected in this Supplement will allow ITU members to evaluate scenarios similar to their own and, therefore, have a higher probability of success by avoiding improper practices, enriching their experience, optimizing investments and improving the scope and complexity of the solutions adopted.

History*

Edition	Recommendation	Approval	Study Group	Unique ID
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Evaluation, key performance indicator, maturity model, smart and sustainable cities, use cases.

* To access the Recommendation, type the URL https://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID.

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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Table of Contents

Supplement 78 to ITU-T Y-series Recommendations

Use cases on implemented or evaluated smart sustainable city solutions based on ITU-T Y.4900 Recommendations series

1 Scope

This Supplement describes use cases of implemented or evaluated smart sustainable cities (SSCs) based on the ITU-T Y.4900 Recommendations series.

This Supplement contains:

- Recommended template for the description of SSC use cases;
- A set of SSC use cases;
- A collection of challenges and opportunities based on the use cases.

2 References

[ITU-T Y.4900] Recommendation ITU-T Y.4900/L.1600 (2016), *Overview of key performance indicators in smart sustainable cities*.

[ITU-T Y.4903] Recommendation ITU-T Y.4903/L.1603 (2022), *Key performance indicators for smart sustainable cities to assess the achievement of sustainable development goals*.

[ITU-T Y.4904] Recommendation ITU-T Y.4904 (2019), *Smart sustainable cities maturity model*.

3 Definitions

3.1 Terms defined elsewhere

This Supplement uses the following terms defined elsewhere:

3.1.1 city [ITU-T Y.4900]: An urban geographical area with one (or several) local government and planning authorities.

3.1.2 city sustainability [ITU-T Y.4900]: The sustainability of a smart city is based on four main aspects:

– Economic: The ability to generate income and employment for the livelihood of the citizens;

– Social: The ability to ensure that the welfare (safety, health, education, etc.) of the citizens can be equitably delivered despite differences in class, race or gender;

– Environmental: The ability to protect the existing as well as the future quality and reproducibility of natural resources;

– Governance: The ability to maintain social conditions of stability, democracy, participation and justice.

3.1.3 smart sustainable city (SSC) [ITU-T Y.4900]: A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental, as well as cultural aspects.

NOTE – City competitiveness refers to policies, institutions, strategies and processes that determine the city's sustainable productivity.

3.2 Terms defined in this Supplement

None.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

ICT Information and Communication Technology

KPI Key Performance Indicator

MCDA Multiple Criteria Decision Analysis

SSC Smart Sustainable City

SSC-MM Smart Sustainable City Maturity Model

U4SSC United for Smart Sustainable Cities

WCAG Web Content Accessibility Guidelines

5 Conventions

None.

6 Introduction

The smart sustainable city maturity model (SSC-MM) [ITU-T Y.4904] provides recommendations for each city to develop its own evaluation model. Sharing experiences related to indicator selection, data collection, maturity assessment plan development and action roadmaps can help ITU members learn how to better implement the SSC-MM.

This Supplement aims to gather use cases from ITU members who have implemented or evaluated SSC-MM based on the ITU-T Y.4900 Recommendation series.

The goal of this Supplement is to provide information and identify challenges and opportunities in the implementation and evaluation of SSC-MM solutions. This will be done based on the ITU-T Y.4900 Recommendation series, across a wide spectrum of realities, such as infrastructure maturity, city size, financial conditions, and other relevant factors.

To support similar initiatives in other countries that decide to engage on this topic, a use case template is proposed to collect use cases, identifying best practices, success stories and lessons learned from countries that have already implemented SSC-MM.

In Annex A, the use case template is presented for interested parties to fill out, with particular emphasis on sub-item 6 which is the core of the use case and represents the greatest source of knowledge in terms of challenges and opportunities perceived using the SSC-MM.

It is important to note that the use case submitted to this document does not necessarily need to be a solution that covers all areas or issues relevant to the implementation or evaluation of an SSC-MM. Some use cases may cover only a restricted area or subset of specific areas of the SSC-MM. Additionally, even within a specific case, a subset of core or additional key performance indicators (KPIs) can be used. In other cases, the use case may involve several areas of SSC-MM and a broader set of indicators. In both situations, the use case can be reported using the suggested template. Furthermore, an SSC-MM solution does not need to be fully implemented or evaluated to be included in the document, since use cases can be updated continuously.

It is expected that the use cases collected in this Supplement will allow ITU members to evaluate scenarios similar to their own and, therefore, have a higher probability of success by avoiding poor practices, enriching the experience, optimizing investments and improving the scope and complexity of the solutions adopted.

7 Challenges and opportunities

Considering the Brazilian and Ecuadorian use cases, it was possible to note challenges and opportunities regarding each implemented maturity model. In the Brazilian use case, the main challenge was adapting the SSC-MM to a developing country, especially because of the necessity to cover all Brazilian cities with different digital realities. To address this challenge, two additional levels were implemented and another dimension called "institutional capabilities" was added. In addition, database handling was a challenge in particular because of accessibility, coverage, granularity, accuracy, timing and indicator metric definitions. In the Ecuadorian use case, the main challenge was increasing the participation of the cities and their diversity. Also, data capture and validation were critical, where even when using templates, sometimes it was necessary to consult with municipalities.

Despite these challenges, both uses cases identified opportunities upon developing their maturity models. The Brazilian use case emphasized the importance of their digital platform to support digital city transformation. It was mentioned that this platform has the potential to foster the creation of city communities with similar profiles and diagnoses, facilitating the exchange of experiences and knowledge. In the Ecuadorian use case, the necessity of using SSC-MM was emphasized to make better use of resources and reduce pollution and poverty. Also, it was observed that city data analysis plays a crucial role in establishing effective public policies in areas such as health, security, mobility, employment and basic services.

8 Conclusions

The objective of both use cases was not to encourage competition between cities but rather to assist them to identify ways of becoming smart sustainable cities (SSCs).

The Brazilian use case pointed out their perceptions concerning initial digital inclusion and innovative solution usage for municipal management. However, it identified gaps such as the necessity to train managers and policy makers, as well as the lack of strategies related to public services. To reduce the dependency on primary data, the Brazilian platform has developed initial city information using secondary data with annual updates, and the ability to use primary data at any time. This flexibility allows the city and public policy policymakers to develop a customized system for management and governance.

In Ecuador, there are plans to carry out annual periodic measurements. Additionally, they have implemented a manual of good practices in smart sustainable cities for the mayors.

Annex A

Recommended template for the description of SSC use cases

The following is the recommended template for the description of SSC use cases:

1 Title

a) Source (Country)

b) Site (Country, Region, Group of Cities or City in which the SSC was implemented/evaluated)

2 Objective (aligned with title, it has explanatory content)

3 Background

a) Current practice (current process/context which will benefit from the implementation of the use case)

b) Need for use case

c) Site ecosystem specifics

4 Description

a) Ecosystem description in terms of actors, stakeholders and business roles involved

b) Contextual description

5 Architectural SSC-MM considerations

a) Indicators (How to map the core and additional indicators to evaluate the city maturity level according to their needs and strategies considering the number of core and additional indicators used from SSC-MM)

b) Performance matrix (How to define the interim target value for each KPI)

c) Maturity assessment (How to deploy the assessment for each recommended maturity level vertical (strategy, infrastructure, data, services and applications, assessment, etc.))

d) Statistical calculation (How to define the KPIs data calculation (setting the weights, scoring for indicators))

e) Data collection (How to collect and process primary and secondary data)

f) Transparency (How to make the results achieved transparent to the stakeholders)

6 Results

a) Evaluation and roadmap (How to conduct the maturity assessment at different stages during the smart city development and determine the performance of the case)

b) Opportunities to use the SSC-MM

c) Challenges to using the SSC-MM

7 Conclusion

8 References

Annex B

Brazil use case

B.1 Brazil use case

The Brazil use case was developed to be implemented potentially in all 5 570 Brazilian cities.

B.2 Objective

This use case describes a Brazilian model for SSC-MM considering its particularities as a developing country. For this proposal, a platform, named inteli.gente, has been developed based on the cities' public policies and with the premise to cover the largest number of cities through this digital tool. In addition, the inteli.gente platform proposes to add two levels to the original SSC-MM to cover cities that may otherwise be excluded from the diagnosis. In this way the inteli.gente platform sets objectives, indicators, practices, and milestones to create a roadmap, which cities can use to become sustainable and smart. Like SSC-MM, the inteli.gente platform is not intended to rank cities. Instead, it was developed to be a tool for policy-makers and city-managers to build their short-, medium- and long-term goals.

B.3 Background

In Brazil, there were existing non-integrated models applied to the cities in the context of smart sustainable cities. The inteli.gente platform is the first initiative to build a comprehensive database for the 5 570 Brazilian cities, which can be used for domestic comparisons.

Due to the large number of cities in Brazil, it is well-known that there are huge differences in terms of ICT usage and sustainable development. In some cases, cities do not use ICT in public services provisioning, while other cities use ICT to offer online services to their citizens, enhancing their self-management capabilities.

Considering these differences, the inteli.gente platform was built to provide diagnostics based on the ITU-T Y.4900 series of Recommendations. The customization of the SSC-MM, for example to expand the maturity levels from five to seven levels, was necessary to evaluate Brazilian cities. Level 1 (Adhesion) and Level 2 (Commitment) were added, while the subsequent levels (from 3 to 7) match the original SSC-MM structure.

Other proposed changes related to the ITU-T Y.4900 series involve indicators and metrics to diagnose cities according to their different digital transformations and levels of sustainable development. In this way, the inteli.gente platform offers a guide (diagnosis, not ranking) for Brazilian cities that are looking for their own development across the short-, medium-, and long-term goals.

B.4 Description

The inteli.gente platform is designed to provide a diagnostic to support the formulation of public policies across all Brazilian cities. The development and implementation of the inteli.gente platform brought together multiple actors. The Brazilian government coordinated multi-stakeholder groups through discussions at the Chamber of Cities 4.0. It was crucial to engage relevant stakeholders, including entities such as the Ministry of Science, Technology and Innovations, the Ministry of Communications and research institutions, such as Renato Archer Information and Technology Center, responsible for modelling; the Centre for Applied Research in Artificial Intelligence-IARA/USP, responsible for the model expansion; and the National Network for Education and Research-RNP responsible for constructing the online platform.

Field visits were made to cities with different local contexts. The goal of these visits was to understand their realities, and to support initial discussions and analysis related to the SSC-MM forecasts. This empirical data served as inputs for the additional maturity levels, developing institutional capabilities and formulating questions for the different maturity levels.

B.4.1 Contextual description

The inteli.gente platform takes into account four dimensions to build balanced conditions for sustainable city development: Economic, Sociocultural, Environmental, and Institutional Capabilities of municipal public management. These dimensions are divided into two evaluation modules. The first module follows [ITU-T Y.4904], including the three pillars: economic, sociocultural, and environmental dimensions, and carries out an analysis of a set of indicators related to sustainable development and ICT development.

The second module represents an adaptation developed by the inteli.gente platform, wherein institutional capabilities of municipal public management are treated as one dimension. This dimension assesses the smart city development by considering key actions for the public administration in terms of strategy, infrastructure, data, services/applications and monitoring.

The city is then classified into different maturity levels for each dimension. The final city maturity level is achieved by calculating the average of the evaluation across the four dimensions. This evaluation methodology does not intend to constitute a ranking of cities; rather it proposes to measure their maturity levels and guide their planning and public policy development processes.

Figure B.1 shows the Brazilian maturity model developed through the inteli.gente platform.

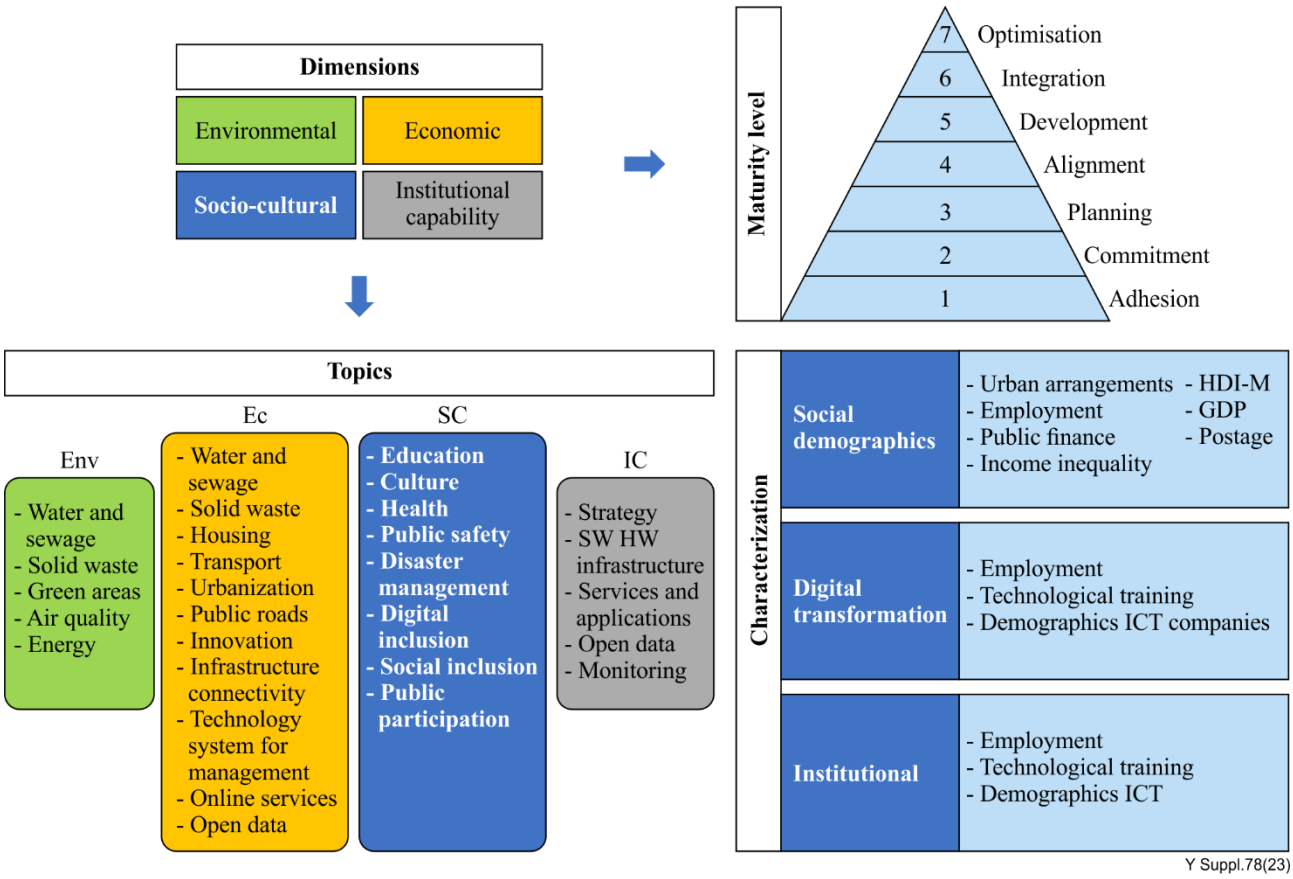

Figure B.1 – Inteli.gente platform

B.4.2 Maturity levels

As shown in Figure B.1, the inteli.gente platform has seven maturity levels, with level 7 being the highest. Levels 1 (Adhesion) and 2 (Commitment) are the result of the adaptation to the Brazilian city realities. The other higher levels follow the SSC-MM, which recommends five maturity levels.

The maturity levels offer a roadmap for cities seeking to achieve their own development in the short-, medium-, and long-term goals. This facilitates the understanding of the complexity, diversity, and nature of the permanent changes they are undertaking. Each level has its objectives, KPIs, and expected practices in each dimension, presenting an evolutionary trajectory towards smart and sustainable cities. The two additional levels from the Brazilian adaptation are as follows:

Level 1: Adhesion

The city recognizes some of its key problems and understands the types of challenges pertinent to becoming an SSC, but there is no formal plan or consolidated strategy for transformation. This level is characterized by asymmetries in infrastructure, service provisioning and public facilities due to insufficient sector integration. The degree of digitalization related to services and processes is low and lacks standardization. Cities at this level have the lowest results for sustainable development indicators and ICTs, which expresses the need for improvement in economic, environmental, and sociocultural aspects.

The achievements at this level may include, but are not limited, to:

– Proposing public policies to promote the benefits of improving the public management of people's lives.
– Proposing public policies with the goal of improving their sociocultural, economic and environmental indicators.

Level 2: Commitment

Transformational actions begin to be articulated. Sectoral goals arise for technology incorporation, even if there is not yet a formal plan or consolidated strategy. Key agents and sectors, as well as technical leaders, lead the digital transformation of the city. There are actions to identify the high-priority areas for investments in basic infrastructure. These priorities include the reduction of asymmetries, standardization of processes and digitalization of public services, as well as capturing of insights for monitoring and evaluating public policies. The indicators of sustainable development and ICTs point out a slight improvement, but there are still persistent infrastructure gaps that have a negative impact on the provisioning of services to the public.

The achievements at this level may include, but are not limited, to:

– Offering tools and paths that cities of this level can use to develop their strategies for sustainable urban development and digital transformation as soon as possible.

B.4.3 Indicators

The indicators are divided into two categories to designate the maturity level: (i) sustainable development and ICT indicators, and (ii) institutional capabilities indicators. The first set of indicators diagnoses maturity level in terms of economic, environmental and sociocultural dimensions. These indicators consider public policy and allow the identification of areas which can be prioritized to achieve sustainable urban development and digital transformation towards the smart city. According to [ITU-T Y.4903], these indicators are key performance indicators (KPI). The second category is the institutional capabilities indicators. These indicators evaluate municipal capabilities associated with planning, governance, integration and interoperability for urban development.

The results are published periodically, with the KPIs being continuously evaluated to track the city's evolution. Annual reviews are conducted, and new indicators may be included to follow the digital transformation and urban development.

The inteli.gente platform also uses other indicators to describe the city's socio-demographic profile, digital transformation and institutional profile. These indicators are called "characterization" indicators and are not used for assigning the maturity level.

B.5 Architectural SSC-MM considerations

B.5.1 Indicators

Table B.1 compares United for Smart Sustainable Cities (U4SSC) and inteli.gente platform indicators regarding core and additional indicators in terms of economy, environment and sociocultural dimensions:

Table B.1 – Comparison between U4SSC and inteli.gente indicators

Dimension	KPIs U4SSC	inteli.gente	%KPIs verified of total KPIs U4SSC
Economy			
Core KPIs	23	19	82.60
Advanced KPIs	22	12	54.54
Environment			
Core KPIs	12	11	91.60
Advanced KPIs	5	1	20.00
Society & Culture			
Core KPIs	20	12	60.00
Advanced KPIs	9	5	55.55
Total	91	60	65.93

These indicators are mapped on inteli.gente platform through the following steps:

– Collection of secondary data from different city areas in order to build indicators.

– Online completion of forms by municipal representatives regarding the city.

– Examination of all information based on the maturity model methodology, assigning a maturity level to the city.

– Provision of the results to municipal managers and public policymakers, including action plans and public policies.

– Annual evaluation of indicators.

B.5.2 Performance matrix

Each indicator has its rating range divided into seven levels of maturity. The criteria for assigning these levels have been established as highlighted below:

– The recommended levels were derived from SSC-MM [ITU-T Y.4904] and adapted by the inteli.gente platform to establish the indicators' range.

– The average and the median values of the indicators were used to define the recommended level intervals.

– Reference information defined by the Brazilian Government and international institutions was used.

– Primary data sources were used, composed of binary data with scores of either one or zero depending on the answer: Yes or No. The overall score is obtained by the sum of the values, leading to subsequent assignment of a level for the related indicators.
– The latest published data by the official source of the municipalities is used, after making the necessary adaptations due to the lack of standardization in extraction methods.

Table B.2 presents the performance matrix with the indicator list and roadmap:

Table B.2 – Performance matrix with the indicator list and roadmap

Dimension	Topics	KPIs	Seventh level Optimization / Sixth level Integration / Fifth level Alignment / Fourth level Development / Third level Planning / Second level Commitment / First level Adhesion						
Economy	Water and sewage	Total population index with water service	from 0% to 35.99%	from 36% to 69.66%	from 69.67% to 83.6%	from 83.7% to 87.78%	from 87.79% to 92.2%	from 92.21% to 99.00%	from 99.01% to 100%
		Total population index with sewage service	from 0% to 31.54%	from 31.55% to 53.19%	from 53.20% to 73.29%	from 73.3% to 87.78%	from 87.79% to 92.2%	from 92.21% to 99.00%	from 99.01% to 100%
		Urban population index with sewage services	from 0% to 31.54%	from 31.55% to 70.1%	from 70.11% to 89.60%	from 89.61% to 92.4%	from 92.41% to 97.99%	from 98.0% to 99.0%	from 99.01% to 100%
	Open data	Open data from municipal management	0 points	2 points	Sum of 3 or 4 points	Sum of 5 or 6 points	Sum of 7 or 8 points	9 points	10 points
	Housing	Percentage of households with a population living in subnormal agglomerates	from 100% to 46.23%	from 46.22% to 24.84%	from 24.83% to 5.60%	from 5.59% to 4.11%	from 4.10% to 1.44%	from 1.43% to 0.59%	below 0.58%
		Housing programs and actions	0 points	sum of 1 or 2 points	Sum of 3 or 4 points	Sum of 5 or 6 points	Sum of 7 or 8 points	Sum of 9 or 10 points	Sum of 11 points
		Precarious urban settlements	Sum of 4 or 3 points	Sum of 2 points	Sum of 1 point	0 points	0 points - tracks the topic level	0 points - tracks the topic level	0 points - tracks the topic level
	Connectivity infrastructure	Scale of access to fixed broadband	from 0% to 4.0%	from 4.01% to 7.72%	from 7.73% to 15.43%	from 15.44% to 23.56%	from 23.57% to 31.34%	from 31.35% to 50%	50.01% and above
		Scale of access to mobile broadband	from 0% to 35.00%	from 35.01% to 45.0%	from 45.01% to 62.00%	from 62.01% to 75.00%	from 75.01% to 87.00%	from 87.01% to 94.79%	94.8% and above
		Coverage of access to mobile broadband by 3G and 4G technologies	0 points	0 points - tracks topic level	0 point- tracks topic level	1 point	2 points	3 points - tracks topic level	3 points - tracks topic level

Table B.2 – Performance matrix with the indicator list and roadmap

Dimension	Topics	KPIs	Seventh level Optimization						
			Sixth level Integration						
			Fifth level Alignment						
			Fourth level Development						
			Third level Planning						
			Second level Commitment						
			First level Adhesion						
		Fiber optic coverage	0 points	0 points - tracks topic level	0 points - tracks topic level	1 point	1 point - tracks topic level	1 point - tracks topic level	1 point - tracks topic level
		Technology network interconnecting public buildings and equipment	0 points	0 points tracks topic level	Sum of 1 point	Sum of 2 points	Sum of 03 points	Sum of 03 points - tracks topic level	Sum of 03 points - tracks topic level
		Range of access to fixed broadband by speed or high speed	0% to 2.03% range	range of 2.04% up to 4.61%	4.62% to 15.78%	range from 15.79% to 23.56%	range from 23.57% to 31.34%	range from 31.35% to 50%	range of 50.01% and above
		Base station numbers	0% to 20% range	21% to 50% range	51% to 62% range	63% to 75% range	76% to 85% range	86% to 99% range	range 100% and above
	Innovation	Professional qualification and labour intermediation	0 points	Sum of 1 to 3 points	Sum of 4 points	Sum of 5 points	Sum of 6 points	Sum of 6 points - tracks the topic level	Sum of 6 points - tracks the topic level
		Urban productive inclusion	0 points	Sum of 1 to 3 points	Sum of 4 points	Sum of 5 or 6 points	Sum of 7 points	Sum of 8 points	Sum of 9 points
		Access to credit, microcredit and insurance	0 points	Sum of 1 to 3 points	Sum of 4 points	Sum of 5 points	Sum of 6 points	Sum of 6 points - tracks the topic level	Sum of 6 points - tracks the topic level
		Generation of work and income in the municipality	0 points	Sum of 1 to 3 points	Sum of 4 points	Sum of 5 points	Sum of 5 points - tracks topic level	Sum of 5 points - tracks topic level	Sum of 5 points - tracks topic level
	Solid Waste	Rate of population covered with waste collection service	0% to 55.12% range	55.13% to 79.99%	80% to 92.1% range	range from 92.11% to 95.11%	95.12% to 98.12%	range of 98.13% up to 99.00%	range from 99.01% to 100%

Table B.2 – Performance matrix with the indicator list and roadmap

Dimension	Topics	KPIs	Seventh level Optimization / Sixth level Integration / Fifth level Alignment / Fourth level Development / Third level Planning / Second level Commitment / First level Adhesion						
		Selective waste collection in the municipality	0 points	0 points	0 points	1 point	1 point - tracks topic level	1 point - tracks topic level	1 point - tracks topic level
	City Hall Online Services	Services on the City Hall website	0 points	Sum of 1 to 4 points	Sum of 5 to 8 points	Sum of 9 to 12 points	Sum of 13 to 16 points	Sum of 17 to 20 points	Sum of 21 to 23 points
	Systems and technology for urban management	City hall geographic information system	0 points	Sum of 1 point	Sum of 2 points	Sum of 3 to 4 points	Sum of 5 to 7 points	Sum of 8 to 9 points	Sum of 10 points
		Command and control centres for city management	0 points	Sum of 1 point	Sum of 2 points	Sum of 3 to 4 points	Sum of 5 points	Six points - from 71.43% to 85.71%	Seven points - from 85.72% to 100%
		Integrated smart city platform	0 points	Sum of 1 point	Sum of 1 point	Sum of 2 points	Sum of 2 points	Sum of 3 points	Sum of 3 points - tracks topic in case of level 7
	Transport	Travel sharing services	0 points	0 points	Sum of 1 point	Sum of 2 points	Sum of 3 points	Sum of 4 points	Sum of 5 points
		Real-time public transportation information service	0 points	0 points	Sum of 1 point	Sum of 2 points	Sum of 3 points	Sum of 4 points	Sum of 4 points - tracks the topic in case of level 7
		Regular passenger transport services	Sum of 0 to 3 points	Sum of 4 to 6 points	Sum of 7 to 9 points	Sum of 10 to 13 points	Sum of 14 to 16 points	Sum of 17 points	Sum of 17 points - tracks the topic in case of level 7
		Smart services and solutions for urban mobility	0 points	0 points	Sum of 1 and 2 points	Sum of 3 and 4 points	Sum of 5 to 7 points	Sum of 8 to 9 points	Sum of 10 points

Table B.2 – Performance matrix with the indicator list and roadmap

Dimension	Topics	KPIs	Seventh level Optimization / Sixth level Integration / Fifth level Alignment / Fourth level Development / Third level Planning / Second level Commitment / First level Adhesion						
		Accessibility in public transport	0 points	Sum 1 point	Sum 2 points	Sum of 3 points	Sum of 4 points	Sum of 5 points	Sum of 5 points - accompanies the topic in case of level 7
		Cycling in the city	0	1 to 2 points	Sum 3 points	Sum 4 points and tracks topic level	Sum 4 points and tracks topic level	Sum 4 points and tracks topic level	Sum 4 points and tracks topic level
	Urbanization of public roads	Paving index of public roads	0% to 45.40%	from 45.41% to 78.28%	from 78.29% to 81.71%	from 81.72% to 87.72%	from 87.73% to 93.73%	from 93.74% to 99.00%	from 99.01% to 100%
Sociocultural	Culture	Structure of cultural and sports equipment	0 points	Sum of 1 to 3 points	Sum of 4 to 7 points	Sum of 8 to 11 points	Sum of 12 to 15 points	Sum of 16 to 21 points	Sum of 22 to 27 points
		Protection of material and immaterial cultural heritage	0 points	Sum of 1 to 2 points	Sum of 3 to 4 points	Sum of 5 points	Sum of 6 points	Sum of 7 points	Sum of 7 points - tracks topic level
		Online services for culture promotion	0 points	0 points	Sum of 1 to 2 points	Sum of 3 points	Sum of 4	Sum of 5 points	Sum of 6 points
		Online cultural services offered to the population	0 points	0 points	Sum of 1 to 3 points	Sum of 4 to 5 points	Sum of 6 points	Sum of 7 points	Sum of 8 points
	Education	Index of technology equipment available in municipal public schools	From 0% to 6%	From 7% to 13%	From 14% to 18%	From 19% to 30%	From 31% to 54%	From 55% to 77%	From 78% to 100%
		Illiteracy rate	From 50% to 20%	From 19.9% to 9.4%	From 9.39% to 6.8%	From 6.79% to 4.8%	From 4.79% to 3%	From 2.9% to 1%	From 0.9% to 0.0%

Table B.2 – Performance matrix with the indicator list and roadmap

Dimension	Topics	KPIs	Seventh level Optimization / Sixth level Integration / Fifth level Alignment / Fourth level Development / Third level Planning / Second level Commitment / First level Adhesion						
		Basic education development index (IDEB) - final years	From 0% to 3.49%	From 3.5% to 4.16%	From 4.17% to 5.0%	From 5.1% to 6.2%	From 6.3% to 7.0%	From 7.1% to 8.9%	From 9.0% to 10%
		Higher education vacancies	0 posts	From 1 to 2000 vacancies	From 2001 to 3000 vacancies	From 3001 to 4000 vacancies	From 4001 to 5000 vacancies	From 5001 to 6000 places	Over 6001 vacancies
		Technological education centres	0 points	Sum 1 point	Sum of 2 points	Sum of 3 to 4 points	Sum of 5 points	Sum of 6 points	Sum of 7 points
		Education actions for specific communities	0 points	Sum 1 point	Sum of 2 points	Sum of 3 points	Sum of 4 points	Sum of 4 points - tracks topic level	Sum of 4 points - tracks topic level
		Age-grade distortion rates	From 100% to 51%	From 50.99% to 31%	From 30.99% to 21%	From 20.99% to 16%	From 15.99% to 11%	From 10.99% to 6%	Below 5.99%
		Percentage of municipal schools with internet access	From 0% to 32.99%	From 33% to 59.99%	From 60% to 70%	From 70.01% to 80%	From 80,015 to 90%	From 90.01% to 99.00%	From 99.01% to 100%
		Computers for student use	From 0 to 500 computers	From 501 to 1000 computers	From 1001 to 1500 computers	From 1501 to 2000 computers	From 2001 to 4000 computers	From 4001 to 6000 computers	Over 6001 computers
	Disaster management	Technology solutions for natural disaster management and monitoring	0 points	Sum of 1 to 2 points	Sum of 3 points	Sum of 4 to 5 points	Sum of 6 to 8 points	Sum of 9 to 10 points	Sum of 11 to 12 points
		Vulnerability to risks and natural disasters	Sum of 6 to 5 points	Sum of 4 to 3 points	Sum of 2 points	Sum of 1 point	0 points	0 points - tracks the topic level	0 points - tracks the topic level
	Digital inclusion	Promotion of digital inclusion	0 points	Sum of 1 to 3 points	Sum of 4 points	Sum 5 to 6 points	Sum of 7 points	Sum of 8 points	Sum of 9 points
		Technological training courses	0 points	Sum of 1 point	Sum of 2 points	Sum of 3 points	Sum of 4 points	Sum of 5 points	Sum of 5 points - tracks topic level

Table B.2 – Performance matrix with the indicator list and roadmap

Dimension	Topics	KPIs	First level Adhesion	Second level Commitment	Third level Planning	Fourth level Development	Fifth level Alignment	Sixth level Integration	Seventh level Optimization
	Social inclusion	Public policies for women	0 points	0 points	Sum of 1 to 3 points	Sum of 4 to 5 points	Sum of 6 to 7 points	Sum of 8 to 9 points	Sum of 10 to 11 points
		Social inclusion for specific groups	0 points	Sum of 1 to 2 points	Sum of 3 to 4 points	Sum of 5 to 7 points	Sum of 8 to 10 points	Sum of 11 to 12 points	Sum of 13 to 14 points
	Public Participation	Face-to-face forms for public participation	Sum of 0 to 1 point	Sum of 2 to 4 points	Sum of 5 to 7 points	Sum of 8 to 10 points	Sum of 11 to 13 points	Sum of 14 to 15 points	Sum of 16 points
		Online forms for public participation	0 points	0 points	Sum of 1 point	Sum of 2 points	Sum of 3 points	Sum of 4 points	Sum of 5 points
	Health	Telemedicine or telehealth services	0 points	0 points	Sum of 1 point	Sum of 2 to 3 points	Sum of 4 to 5 points	Sum of 6 to 8 points	Sum of 9 points
		Hospital beds in the municipal public network	0 beds	From 1 to 169 beds	From 170 to 248 beds	From 249 to 496 beds	From 497 to 887 beds	From 888 to 1199 beds	1200 and above
		Doctors available in the municipal public network	0 doctors	From 1 to 72 doctors	From 73 to 103 doctors	From 104 to 134 doctors	From 135 to 164 doctors	From 165 to 194 doctors	From 195 and above
		Electronic medical record	0 points	Sum 1 point	Sum of 1 point	Sum of 2 points	Sum of 2 points - accompanies topic	Sum of 2 points - accompanies topic	Sum of 2 points - accompanies topic
		Online health services offered to patients	0 points	0 points	Sum of 1 to 3 points	Sum of 4 to 5 points	Sum of 6 points	Sum of 7 points	Sum of 8 points
		Risk index and health protection of live births	From 1% to 0, 4%	From 0.39% to 0.18%	From 0.1799% to 0.13%	From 0.1299% to 0.095%	From 0.0949% to 0.055%	From 0.0549% to 0.015%	From 0.0149% to 0%
	Public security	Monitoring solutions for public safety	0 points	0 points	Sum of 1 point	Sum of 2 points	Sum of 3 points	Sum of 4 points	Sum of 5 points
		Homicide rate	Above 92%	From 91.99% to 31.60%	From 31.59% to 22.38%	From 22.37% to 14.10%	From 14.09% to 7.10%	From 7.09% to 1.99%	1.98% to 0%

Table B.2 – Performance matrix with the indicator list and roadmap

Dimension	Topics	KPIs	First level Adhesion		Second level Commitment	Third level Planning	Fourth level Development	Fifth level Alignment	Sixth level Integration	Seventh level Optimization
		Public policies and actions for public security	0 points	Sum 1 point	Sum of 2 to 3 points	Sum of 4 to 5 points	Sum of 6 to 7 points	Sum of 8 points	Sum of 9 points	
Environmental	Water and sewage	Volume of sewage collected	From 0% to 36.51%	From 36.52% to 53.10%	From 53.11% to 63.76%	From 63.77% to 78.43%	From 78.44% to 87.02%	From 87.03% to 99.00%	From 99.01% to 100%	
		Average water consumption per capita	Upper limit above 250 litres / hab day Lower limit below 50 litres / hab	Upper limit of 249.9 litres / person per day at 154.89 litres / person per day Lower limit of 50.01 litres / person per day at 70 litres / person per day	Upper limit of 154.88 litres / person per day to 150 litres / person per day Lower limit of 70.01 litres / person per day to 90 liters / person per day	Upper limit of 149 litres / person per day at 130 litres / person per day Lower limit of 90.01 litres / person per day at 100.99 litres / person per day	From 129 litres / day to 120 litres / day	From 119 litres / day to 111 litres / day	From 110 litres / day to 101 litres / day	
		Smart solutions for water distribution and consumption management	0 points	Sum of 1 point	Sum of 2 points	Sum of 3 points	Sum of 4 points	Sum of 5 points	Sum of 6 points	
		Loss rate in water distribution	From 100% to 94.43%	From 94.42% to 43.48%	From 43.47% to 38.4%	From 38.5% to 32.5%	From 32.4% to 20, 78%	From 20.77% to 0.09%	From 0.08% to 0%	
		Volume of treated sewage volume	From 0% to 0.9%	From 1% to 23%	From 23.01% to 46.29%	From 46.30% to 69.99%	70% to 85%	From 85.01% to 99%	From 99.01% to 100%	
	Green areas	Protection and management of the environment and green areas of the municipality	0 points	Sum of 1 to 2 points	Sum of 3 to 4 points	Sum of 5 to 6 points	Sum of 7 to 8 points	Sum of 9 to 10 points	Sum of 11 points	
	Energy	Intelligent solutions for managing electricity consumption	0 points	Sum of 1 point	Sum of 2 points	Sum of 3 to 4 points	Sum of 5 to 7 points	Sum of 8 points	Sum of 9 points	

Table B.2 – Performance matrix with the indicator list and roadmap

Dimension	Topics	KPIs	First level Adhesion	Second level Commitment	Third level Planning	Fourth level Development	Fifth level Alignment	Sixth level Integration	Seventh level Optimization
		Solutions for remote management of public lighting	0 points	Sum of 1 point	Sum of 1 point - track topic	Sum of 1 point - track topic	Sum of 2 points	Sum of 2 points - accompanies topic	Sum of 2 points - accompanies topic
	Air quality	Solutions for monitoring greenhouse gases and air quality	0 points	Sum of 1 to 2 points	Sum of 3 to 4 points	Sum of 5 to 6 points	Sum of 7 to 9 points	Sum of 10 to 13 points	Sum of 14 to 15 points
		Air quality monitoring	0 points	1 point sum	Sum of 2 points	Sum of 3 points	Sum of 4 points	Sum of 4 points - tracks topic level	Sum of 4 points - tracks topic level
	Resource management	Percentage of material collected by selective collection	From 0% to 1%	From 1.1% to 2%	From 2.1% to 3%	From 3.1% to 8.99%	From 9.0% to 25.99%	From 26% to 49.99%	50% to 100%
		Smart solutions for waste collection optimization	0 points	0 points	Sum of 1 point	Sum of 2 points	Sum of 3 points	Sum of 4 points	Sum of 4 points - tracks topic level

B.5.3 Maturity assessment

The institutional capabilities dimension assesses the smart city maturity through the recommended achievements related to strategy, infrastructure, data, services/applications and monitoring. Unlike the other three dimensions, institutional capabilities indicators use the socio-demographic, digital transformational and institutional profiles to adapt their values according to the city's reality. Table B.3 shows the indicators related to each recommended achievement:

Table B.3 – Institutional capabilities indicators

Institutional capabilities	
Topics/axes	**Indicators**
Strategy	ICT incorporation – Priority areas
Strategy	Head of technological governance
Strategy	Head of collaborative governance
Strategy	Strategic plan – Digital transformation
Strategy	ICT incorporation in municipal management
SW HW infrastructure	ICT staff – Size
SW HW infrastructure	ICT organizational structure
SW HW infrastructure	Head of ICT governance
SW HW infrastructure	ICT governance – Practices
SW HW infrastructure	Hardware and software infrastructure – Storage
Service applications	Online public services
Service applications	Public service request
Service applications	Integrated data management
Open data	Data security – Practices
Open data	Transparency – Budget and financial execution
Open data	Data transparency – Availability
Monitoring	Public policy security
Monitoring	Transparency
Monitoring	Perception of public services

B.5.4 Statistical calculation

The inteli.gente platform statistical method is a multiple criteria decision analysis (MCDA) method [b-MCDA], which is based on successive developmental stages achieved by combining and summarizing outcomes from different indicators. This statistical process for determining the maturity level of sustainable development and ICTs in the city is as follows:

1) Use of primary and secondary data sources. The gross value is employed in case the data are not ready (primary data).
2) Definition of the maturity level intervals for each indicator. As a result of this step, the interval matrix was achieved through normalization using the minimum and maximum values of each indicator.
3) Development of the scale transformations for the indicators, using the seven levels. In some cases, formulas were developed.

4) Definition of statistical weights for the indicators according to their relevance and type. These weights are very significant in the model and reflect the degree of importance of each indicator.

5) Calculations of the numerical value for each topic, considering the associated indicators. The weighted value is achieved by summing the normalized values of each indicator, multiplied by their respective weights, and then dividing by the sum of the weights of the indicators related to the topic.

6) Calculations of the numerical value for each dimension by aggregating related topics.

7) The city maturity level is obtained through a weighted average of the four dimensions.

During the procedure described, techniques such as Bloxplot and standard deviation methods are used to handle outliers.

B.5.5 Data collection

The data collection includes primary and secondary data sources. The latter takes indicators from the public database that sometimes-require numeric transformation. Also, the information available for all or most of the Brazilian cities was an important consideration when choosing indicators. The primary collection was chosen using a self-declaration form through the platform, filled out by municipal public managers. Whenever these questions are answered, the maturity level is recalculated, rendering dynamism to the platform, and providing real-time recommendations and diagnoses.

B.5.6 Transparency

The data is available in the inteli.gente platform through different access profiles: public, city halls/municipal managers, and federal policy makers. This arrangement is designed to follow Brazilian data protection regulation.

B.6 Results

B.6.1 Evaluation and roadmap

The inteli.gente platform considers four dimensions: economic, environmental, sociocultural and institutional capabilities. Within the institutional capabilities dimension, the smart city assessment has been broken down into indicators, aiming to facilitate the municipal management understanding, as well as to promote concrete action mapping. This straightforward result presentation allows municipal policymakers to act and progress to the next level.

The platform [b-Inteli.gente] presents the city maturity level score obtained through MCDA for every Brazilian city. This score reflects the city's maturity level, including values for each dimension and their corresponding topics. In addition, the platform provides a socio-demographic profile for each city as complementary information.

Table B.4 presents the results stratified for 5 570 Brazilian cities based on maturity level analysis for each dimension. The data were collected from December 2021 to April 2023. It was observed that the city maturity level 3 emerges as the most predominant, while the institutional capabilities dimension exhibited mainly lower maturity values compared to the other dimensions.

Table B.4 – Number of Brazilian cities by maturity levels

Dimensions	Maturity levels						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Economic	0	219	2 512	2 260	553	26	0
Environmental	263	2 418	1 919	964	5	1	0
Sociocultural	0	353	4 513	685	19	0	0
Institutional capabilities	63	4 991	506	4	2	4	0

The economic dimension exhibits the highest city concentration at maturity levels 3 and 4, comprising 2 512 and 2 260 cities, respectively. There are no cities at maturity levels 1 and 7. The remaining cities are distributed across maturity levels 2, 5 and 6 with 219, 553 and 26 cities respectively.

In the context of the environment dimension, city concentration is spread across maturity levels 2, 3 and 4 encompassing 2 418, 1 919 and 964 cities respectively. Maturity level 1 has 263 cities while the higher maturity levels 5, 6 and 7 have fewer cities with 5, 1 and 0, respectively.

Concerning the sociocultural dimension, Brazil lacks cities at maturity levels 1, 6 and 7. The highest concentration of cities is at levels 3 and 4 comprising 4 513 and 685 cities respectively. Maturity levels 2 and 5 have 353 and 19 cities, respectively.

Finally the institutional capability dimension has the highest concentration of cities at maturity levels 2 and 3 encompassing 4 991 and 506 cities respectively. The other maturity levels (1, 4, 5, 6 and 7) have inexpressive representation with 63, 4, 2, 4 and 0 cities respectively.

This outcome reflects the characteristics of a country in the global south, where municipal planning has not yet become a reality in local governance, despite the results from the other dimensions indicating that the country has implemented actions and programs for development.

Furthermore, the inteli.gente platform allows public policy-makers to conclude that the maturity level does not appear to be dependent on the population size, or even on the city network influence.

B.6.2 Opportunities to use the SSC-MM

Developing a smart city maturity assessment model is complex and requires observing several areas of the city. Therefore, the use of an international reference model helped to maintain the objective of building the Brazilian model.

However, the critical challenge is not only translating the international maturity model and its indicators into the Brazilian context but also in expanding them to reflect digital transformation in an emerging country such as Brazil. Consequently, the inteli.gente platform includes specific aspects, such as different socio-spatial concerns, disparities in ICT utilization within municipal administrations, the promotion of institutional capabilities and a perspective on the city that considers its sustainable development.

The inteli.gente platform integrates indicators, institutional capabilities, and the use of ICT to provide a comprehensive city diagnostic. It is not used just for monitoring the goals achievement, the use of ICT advancement, the quality of services improvement, or the specific problems fixed. The inteli.gente platform is intended to be a tool to support the management and digital transformation of the city.

Based on the assessment of the maturity levels across several Brazilian cities, it is possible to foster the creation of city communities with similar profiles and diagnoses. This collaborative environment enables the exchange of experiences and knowledge to deal with the challenges

associated with the transforming into smart cities. The inteli.gente platform can also be used, tested, and improved by other countries in Latin America with a similar context.

B.6.3 Challenges to use of the SSC-MM

Contextualization challenge of an international model

One of the biggest challenges related to the development of the inteli.gente platform refers to the context in which most maturity models are built [b-Huovila] [b-Backhouse]. Most maturity models have been done in developed countries, focusing on their problems [b-Kreimer]. In addition, maintaining conceptual alignment with the original reference model was a challenge evidenced during the process of adaptation and expansion. The ITU-T Y.4904 model uses a single city for evaluation and self-comparison to measure its progression over time. In the case of the inteli.gente platform, the evaluation is carried out for all Brazilian cities simultaneously, necessitating the development of symmetric evaluation mechanisms that can be applied to them.

Diversity was also a concern that was necessary to be added to the inteli.gente platform. This challenge derived from the necessity of covering all Brazilian cities, with different digital transformation levels or some which had not even experienced the possibility of using ICT. Some cities in Brazil are digitally excluded, dependent on public resources and hardly able to design public policies extracted from ICT benefits. Based on these different needs and challenges, the proposed indicators were required to consider such territorial disparities.

The selected indicators are intended to represent an area or themes within public policy or city management. The themes diagnosed by the inteli.gente platform are selected based on the topics of the international model.

Data capture and identification challenge

Some challenges were found while mapping databases, especially related to accessibility, coverage, granularity, accuracy, and timing. Regarding data accessibility, many platforms are difficult to handle and require advanced user skills to consult and extract information. Also, it was noted that the available indicators were not grouped according to the city level, impacting data granularity and coverage across all Brazilian cities.

The data accuracy and timing were other challenges in indicator selection. Some databases contained unreliable or inaccurate and incomplete information. Consequently, a decision was made to restrict the data set collection to a maximum period of 10 years. In the case of lacking open databases, primary collection was adopted through self-declared questionnaires.

Indicator metric challenge

The city database diversity was a challenge during the indicator metric definition. For example, the water and sewage collection indicators use percentages, whereas the homicide rate and the number of doctors/beds are measured per 100 thousand inhabitants. Meanwhile, the existence of selective garbage collection is treated with binary variables (yes or no).

The ITU-T Y.4904 model does not specify how to carry out this data transformation or the statistical model to assess the different maturity levels. Therefore, the challenge was to develop a unified calculation structure capable of integrating different indicator types, sourced from different databases, to reach the seven maturity level across cities.

B.7 Conclusions

The Brazilian maturity model for smart sustainable cities (SSCs) has been developed to customize the SSC-MM recommendations for the reality of developing countries. Table B.5 shows the main differences:

Table B.5 – Main differences between SSC-MM and inteli.gente platform

	SSCMM-ITU	inteli.gente platform
Multidimensionality	3 dimensions: Economic, Environment, Sociocultural.	4 dimensions: Economic, Environment, Sociocultural and Institutional capabilities. In addition, city's socio-demographic, digital transformation and institutional profile are used through characterization.
Level	5 levels	7 Levels. Two new levels: Level 1 – Adhesion, Level 2 – Commitment and the others higher levels follow the SSC-MM.
Axes	5 axes	5 axes included at the Institutional capacities dimension.
Characteristics/ Properties/Attributes	CORE: Key indicators that all cities should consider when performing the maturity assessment. It is recommended that target values be achieved for all key indicators listed at a given level for cities to claim that they have reached that level.	They are relevant indicators to provide essential information to discriminate the technological evolution, the urban structure, and the ICT for a smart city. They follow the evolution of the city's performance and reflect the changing conditions of the economic, sociocultural, and environmental dimensions of the model. Still, they follow an evolutionary logic to drive the diagnosis of urban infrastructures and advances in ICT.
	Additional: indicators that cities could consider when developing their own maturity assessment plan and when executing the maturity assessment.	They are indicators with attributes in technology and innovation that guide actions and public policies in the city. They are indicators that complement the information of the Core indicators in each theme and/or topic and still meet the needs of services and applications with the use of ICT.
	Weights: can be used to reflect their degree of importance in the digital transformation of sectors. It can be used to define the weight of each indicator(s) and should determine the weights of all aspects and key areas.	Weights are split into three levels: a) High relevance: these weights are directly linked to the thematic areas of public policies and are applied to the themes of each dimension of sustainable development; b) Intermediate relevance: these weights enable the assessment of the evolution of ICT solutions and the improvement of the urban infrastructure within the city; c) Low relevance: these weights are considered less relevant and act in the provisioning of services, as well as the implementation of integrated solutions and applications in the city.
Source	Secondary bases	Primary bases from public self-declarable forms and secondary bases.

Based on the results extracted from the inteli.gente platform some conclusions can be drawn, including a) an initial perspective on digital inclusion within Brazil; b) use of innovative solutions in municipal management; c) necessity for training managers and policymakers; d) necessity for planning and strategy to elevate the quality of public services offered to the population.

To make better decisions, cities can receive support from the IARA/USP through the adoption of intelligent solutions and services. Moreover, starting from Jan/2023, the inteli.gente platform has taken accessibility into account. Consequently, inteli.gente platform has implemented features for navigation, ensuring compliance with WCAG standards for aspects like pounds and colours.

B.8 References

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[b-U4SSC] *U4SSC Collection Methodology for Key Performance Indicators for Smart Sustainable Cities*, United for Smart Sustainable Cities.

[b-WCAG] Web Content Accessibility Guidelines – https://www.w3.org/TR/2018/RECWCAG21-20180605/

Annex C

Ecuador use case

C.1 Ecuador use case

Measurement of the maturity level of smart sustainable cities and communities in Ecuador with the implementation of [ITU-T Y.4903], [ITU-T Y.4904] and the U4SSC *Collection Methodology for Key Performance Indicators for Smart Sustainable Cities* [b-U4SSC].

Ecuador has 24 provinces; these are made up of a total of 221 cantons, whose level of government is municipal, they are called decentralized autonomous municipal governments (GADMs). The Ministry of Telecommunications and the Information Society invited all the 221 cantons or municipalities of Ecuador to participate in the processes of measuring the maturity level of smart and sustainable cities, which were carried out between the years 2020 and 2022.

For the first measurement carried out in the year 2020 the 50 cantons that provided the information on maturity levels and KPIs are considered. In 2020, a final ranking was prepared with the average maturity level obtained in the achievement evaluation and the KPI evaluation.

For the second measurement carried out in the year 2022, there was a participation of 60 cantons that delivered the inputs to carry out their measurement. In the year 2022 it was decided not to establish a final ranking, so that the evaluated cities are not considered better or worse than others. On this occasion, the achievement maturity level and the KPI maturity level are presented separately.

Figure C.1 shows the 50 participating cantons in the year 2020 and Figure C.2 shows the 60 participating cantons in the year 2022.

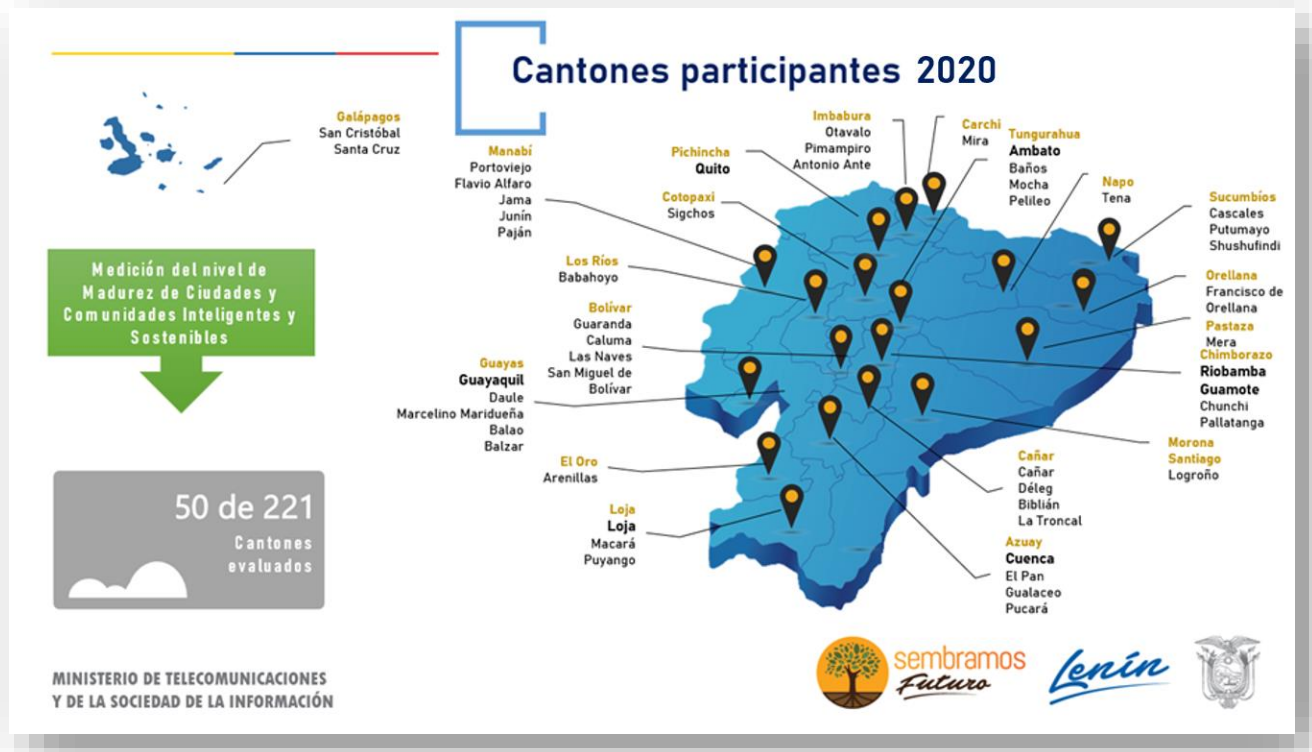

Figure C.1 – 50 participating cantons in the year 2020

Figure C.2 – 60 participating cantons in the year 2022

C.2 Objective

In accordance with [ITU-T Y.4904] *Smart sustainable cities maturity model* a survey is established to measure maturity level.

The survey of recommended achievements makes it possible to measure the maturity level of decentralized autonomous municipal governments (GADMs) in the following areas:

- Strategy (E)
- ICT infrastructure (I)
- Data (D)
- Services and applications (S)
- Evaluation (V).

The maturity levels, ranging from 1 to 5, are assigned based on the achievements realized, following analysis of responses to 39 Yes/No self-assessment questions by GADMs.

In accordance with [ITU-T Y.4903] *Key performance indicators for smart sustainable cities to assess the achievement of sustainable development goals* a survey is established to assess maturity levels in this regard.

In order to establish criteria to assess the contribution of ICTs to making cities smarter and more sustainable, 91 key performance indicators (KPIs) were defined as part of a view of city performance in three different dimensions, considering that ICTs cut across all of them:

- Economy
- Environmental
- Society and culture.

Under the United for Smart and Sustainable Cities (U4SSC) initiative, it is considered that each city will have three to six months to collect the data for the 91 KPIs.

Both in the year 2020 and in 2022, the collection of the information took about 4 months, and the processing 2 months.

C.3 Background

The aim of the Digital Ecuador Policy is to transform the country into an economy based on digital technologies through the bridging of the digital divide, development of the information and knowledge society, digital government, efficiency in public administration and adoption of the digital in social and economic sectors. Analysing city-generated data is fundamental to the establishment of public policy aimed at stimulating the economy and creating jobs, etc. The Smart Sustainable Cities project is aligned with the Innovative and Competitive Ecuador programme, which promotes innovation in industry through the use of ICTs.

After obtaining the results we proceeded to prepare for each of the measured cities, their own *Manual of Good Practices for Smart and Sustainable Cities* based on the results obtained by the city. This document establishes the recommendations so that the canton can reach its objective of being a smart or sustainable city or community.

In the year 2020 it was defined to carry out the measurement again in the year 2022; however, it is now planned to carry out the measurement process annually.

However, if any city wishes to measure its level of maturity and key performance indicators, from MINTEL we are ready to advise and facilitate all the inputs developed.

The analysis of data generated by cities is a major resource for countries in overcoming challenging times. Data analysis is crucial to the establishment of public policies for health, security, mobility, employment, basic services, etc.

No changes were made to the ITU-T Y.4904 application. An online survey was implemented to collect the necessary information.

In relation to [ITU-T Y.4903], of the 91 recommended indicators, 45 the KPIs were requested from the Municipalities and the Public Institutions. No Municipality was able to obtain all the indicators and the public institutions sent information on 17 of them (in the 2020) and 8 (in the 2022). The results were reported in an Excel matrix.

With this precedent, it was necessary to adjust the indicator for the number of public WIFI access points in the city, adjusting it to a ratio per 100 000 inhabitants.

C.4 Description

Cantons that attended the virtual workshops, who completed the online survey and those who delivered the KPI matrix can be determined from Tables C.1 and C.2.

Year 2020

Table C.1 – Monitoring of the measured cantons, year 2020

CANTÓN	Asistió a Taller	Encuesta Web	Matriz KPI	CANTÓN	Asistió a Taller	Encuesta Web	Matriz KPI	CANTÓN	Asistió a Taller	Encuesta Web	Matriz KPI
Cuenca	SI	SI	SI	Balzar	SI	SI	SI	Huamboya	SI	SI	NO
Gualaceo	SI	SI	SI	Daule	SI	SI	SI	Logroño	SI	SI	SI
Paute	SI	SI	NO	Milagro	NO	SI	NO	Pablo Sexto	SI	SI	NO
Pucará	SI	SI	SI	Coronel Marcelino Maridueña	SI	SI	SI	Tena	NO	SI	SI
Sigsig	SI	NO	SI	Antonio Ante	SI	SI	SI	Mera	SI	SI	SI
El Pan	SI	SI	NO	Otavalo	SI	SI	SI	Quito	SI	SI	SI
Guaranda	NO	SI	SI	Pimampiro	SI	SI	SI	Ambato	SI	SI	SI
San Miguel de Bolívar	SI	SI	SI	Loja	SI	SI	SI	Baños	SI	SI	SI
Caluma	SI	SI	SI	Macará	SI	SI	SI	Mocha	NO	SI	SI
Las Naves	SI	SI	SI	Puyango	SI	SI	SI	Patate	SI	SI	NO
Biblián	SI	SI	SI	Olmedo	SI	SI	NO	Quero	SI	SI	NO
Cañar	SI	SI	SI	Babahoyo	SI	SI	SI	San Pedro de Pelileo	SI	SI	SI
La Troncal	NO	SI	SI	Baba	SI	SI	NO	Santiago de Píllaro	SI	SI	NO
Déleg	NO	SI	SI	Quevedo	SI	SI	NO	El Pangui	SI	SI	NO
Mira	SI	SI	SI	Quinsaloma	SI	SI	NO	Centinela del Cóndor	SI	SI	NO
San Pedro de Huaca	SI	SI	NO	Portoviejo	SI	SI	SI	Palanda	SI	SI	NO
Sigchos	SI	SI	SI	Flavio Alfaro	SI	SI	SI	Paquisha	SI	SI	NO
Riobamba	SI	SI	SI	Jipijapa	NO	SI	NO	San Cristóbal	SI	SI	SI
Chunchi	SI	SI	SI	Junín	SI	SI	SI	Santa Cruz	NO	SI	SI
Guamote	SI	SI	SI	Manta	SI	SI	NO	Putumayo	SI	SI	SI
Pallatanga	SI	SI	SI	Paján	SI	SI	SI	Shushufindi	SI	SI	SI
Arenillas	SI	SI	SI	Pichincha	SI	SI	NO	Cascales	SI	SI	SI
Pasaje	SI	SI	NO	24 de Mayo	NO	SI	NO	Francisco de Orellana	SI	SI	SI
Guayaquil	SI	SI	SI	Jama	SI	SI	SI	Aguarico	SI	SI	NO
Balao	SI	SI	SI	Sucúa	SI	SI	NO	Loreto	SI	SI	NO

There was a participation of 114 municipalities and 28 public institutions in 22 virtual workshops. 75 cantons provided the information on achievement maturity level. 51 cantons sent the information on key performance indicators. Five public institutions submitted 17 indicators.

Year 2022

Table C.2 – Monitoring of the measured cantons, year 2022

CANTÓN	Asistió a Taller	Encuesta	Matriz KPI	CANTÓN	Asistió a Taller	Encuesta	Matriz KPI	CANTÓN	Asistió a Taller	Encuesta	Matriz KPI
Cuenca	SI	SI	SI	Daule	SI	SI	SI	Manta	SI	SI	SI
Santa Isabel	SI	SI	SI	El Empalme	SI	SI	SI	Santa Ana	SI	SI	NO
Chordeleg	SI	SI	SI	Urbina Jado (Salitre)	SI	SI	SI	Morona	SI	SI	NO
Camilo Ponce Enriquez	SI	SI	SI	Isidro Ayora	SI	SI	SI	Taisha	SI	SI	SI
Guaranda	SI	SI	SI	Ibarra	SI	SI	NO	Archidona	SI	SI	SI
San Miguel	SI	SI	SI	Cotacachi	SI	SI	SI	El Chaco	SI	SI	NO
Biblián	SI	SI	SI	Loja	SI	SI	SI	Mera	SI	SI	SI
Tulcán	SI	SI	SI	Paltas	SI	SI	NO	Santa Clara	SI	SI	SI
La Maná	SI	SI	SI	Pindal	SI	SI	SI	Arajuno	SI	SI	SI
Salcedo	SI	SI	SI	Montalvo	SI	SI	SI	Quito	SI	SI	SI
Riobamba	SI	SI	SI	Quevedo	SI	SI	SI	Pedro Vicente Maldonado	SI	SI	SI
Alausí	SI	SI	SI	Ventanas	SI	SI	SI	Ambato	SI	SI	SI
Chambo	SI	SI	NO	Palenque	SI	SI	SI	Baños	SI	SI	NO
Guano	SI	SI	SI	Valencia	SI	SI	SI	Chinchipe	SI	SI	SI
Machala	SI	SI	SI	Quinsaloma	SI	SI	SI	El Pangui	SI	SI	SI
Pasaje	SI	SI	SI	Portoviejo	SI	SI	SI	San Cristóbal	SI	SI	SI
Piñas	SI	SI	SI	Bolívar	SI	SI	SI	Santa Cruz	SI	SI	SI
Muisne	SI	SI	NO	Chone	SI	SI	SI	Putumayo	SI	SI	SI
Guayaquil	SI	SI	NO	El Carmen	SI	SI	SI	Shushufindi	SI	SI	SI
Balao	SI	SI	SI	Junín	SI	SI	SI	Santo Domingo	SI	SI	SI

There was a participation of 112 municipalities and 14 public institutions in 14 virtual workshops. 60 cantons provided the information on achievement maturity level. 51 cantons sent the information on key performance indicators. Five public institutions submitted 8 indicators.

C.4.1 Contextual description

Maturity level survey

In accordance with [ITU-T Y.4904] *Smart sustainable cities maturity model*, a survey is established to measure maturity level.

The survey of recommended achievements makes it possible to measure the maturity level of decentralized autonomous municipal governments (GADMs) in the following areas:

- Strategy (E)
- ICT infrastructure (I)
- Data (D)
- Services and applications (S)
- Evaluation (V).

The maturity levels, ranging from 1 to 5, are assigned based on the achievements realized, following analysis of responses to 39 Yes/No self-assessment questions by GADMs.

Maturity level 1

At this level, the main goal that the city needs to meet is to have a city SSC strategy with an associated plan. Local decision-makers of the city have developed an overall SSC goal and vision. A clear roadmap or strategic plan is ready to pave the way for ICT-enabled SSC developments. An overall city governance is also put in place to manage the SSC development.

Maturity level 2

The goal that the city needs to meet at this level is to align SSC initiatives with the city's SSC strategy, for example, to deploy ICT infrastructures to support operations and activities for SSC development.

Maturity level 3

The goal that the city needs to meet at this level is that specific SSC initiatives are deployed, SSC services are provided based on ICT infrastructures via for example, local community service centres, mobile applications and web portals.

Maturity level 4

The goal that the city needs to meet at this level is to ensure that systems and data are integrated to deliver municipal services. Technologies such as Internet of things (IoT), cloud computing, artificial intelligence and other advanced technologies may be applied to improve service quality and interoperability.

Maturity level 5

The goal that the city needs to meet at this level is continual SSC improvement. Each of the city services is studied to determine ways to increase value to citizens while reducing operational costs. It is expected that collaboration among systems, data, innovative services and applications will continuously boost city value creation and citizen's happiness. Enhanced effectiveness and efficiency in city management continue to contribute to the city's long-term SSC vision.

C.4.2 Key performance indicators

In accordance with [ITU-T Y.4903] *Key performance indicators for smart sustainable cities to assess the achievement of sustainable development goals*, a survey is established to assess maturity level in this regard.

In order to establish criteria to assess the contribution of ICTs to making cities smarter and more sustainable, 91 key performance indicators (KPIs) were defined as part of a view of city performance in three different dimensions: economy; environmental; and society and culture, considering that ICTs cut across all of them.

GADMs have been identified as the source of information for 45 (in year 2000) 52 (in year 2022) of the KPIs, while the other 46 have various institutions as the primary source of information.

Under the United for Smart and Sustainable Cities (U4SSC) initiative, it is considered that each city will have three to six months to collect the data for the 91 KPIs.

Classification of KPIs and information sources

The 91 categories are organized according to the different dimensions and sub-dimensions with an indication as to whether they are reported by a GADM or institution. Information sources are classified according to the competencies of each of the institutions, which can be a GADM or public institution. Figure C.3 shows the indicator types.

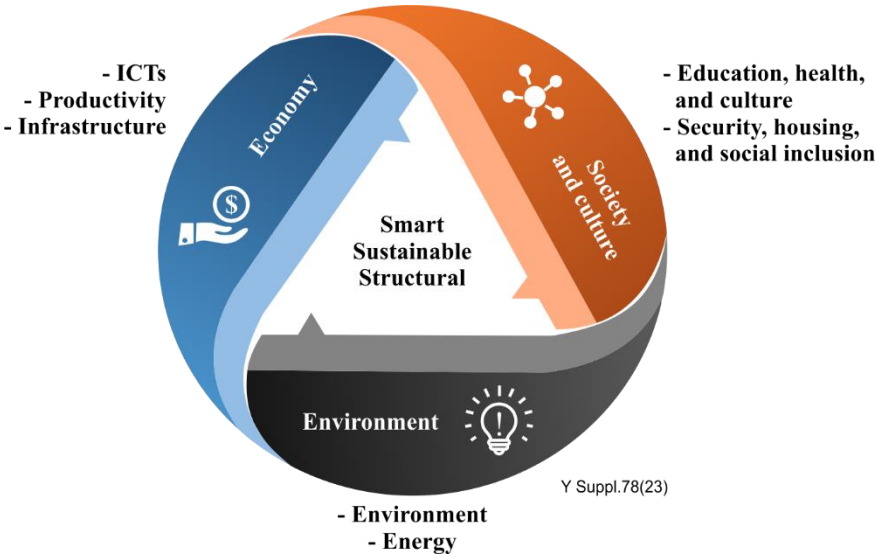

Figure C.3 – Types of indicators

The institutions should report KPI values for each canton in an Excel file.

For the elaboration of the good practices guide, the generation of graphs, recommendations and maturity level of each KPI was automated using Excel in order to present the standardized results in a friendly way for the Mayors and their technical teams.

C.5 Architectural SSC-MM considerations

C.5.1 Indicators

The maturity levels of [ITU-T Y.4904] and the KPIs of [ITU-T Y.4903] are used. With the adjustment of the indicator of Number of wi-fi points per 100 000 inhabitants.

The maturity levels, ranging from 1 to 5, are assigned based on the achievements realized, following analysis of responses to 39 Yes/No self-assessment questions by GADMs.

Each question of the maturity level survey is coded for later analysis.

Maturity level 1

At this level, the main goal that the city needs to meet is to have a city SSC strategy with an associated plan. Local decision-makers of the city have developed an overall SSC goal and vision. A clear roadmap or strategic plan is ready to pave the way for ICT-enabled SSC developments. An overall city governance is also put in place to manage the SSC development. Table C.3 lists the questions used to determine the Achievements maturity level 1.

Table C.3 – Questions to determine the Achievements maturity level 1

ACHIEVEMENTS	**ID**
The city has developed a detailed strategy to reach out to the relevant stakeholders, including the evaluation of budget, resources and costs related to SSC development	E1.1
Key ICT infrastructures are identified to support SSC initiatives	I1
There is a designated official or administrative team with the responsibility to implement the SSC strategy, coordinate and oversee all smart city initiatives, facilitate coordination and identify synergies between them	E1.2
Common terminologies relating to SSC and common reference model are agreed	E1.3
Key data issues are identified in the GADM strategy	D1
Strategies and priorities for services and applications on city level are identified	S1
Assessment plan is ready	V1

Maturity level 2

The goal that the city needs to meet at this level is to align SSC initiatives with the city's SSC strategy, for example, to deploy ICT infrastructures to support operations and activities for SSC development. Table C.4 lists the questions used to determine the Achievements maturity level 2.

Table C.4 – Questions to determine the Achievements maturity level 2

ACHIEVEMENTS	**ID**
The city's initiatives are aligned with the established strategy	E2
The infrastructure development plan is ready and aligned with the city's overall SSC roadmap	I2.1
ICT infrastructures can operate independently to provide various SSC services	I2.2
Ontology[1] and methodology to identify, capture, organize and utilise data are established	D2
Domain services and applications are operated by particular systems	S2
Records of ICT infrastructures are built and periodically updated	I2.3
Self-assessment on ICT infrastructure and services that is conducted periodically	V2

Maturity level 3

The goal that the city needs to meet at this level is that specific SSC initiatives are deployed, SSC services are provided based on ICT infrastructures via for example, local community service centres, mobile applications and web portals. Table C.5 lists the questions used to determine the Achievements maturity level 3.

[1] *Ontology* is a formal definition of the categories, properties and relations between entities that substantiate one, many or all domains of discourse. An ontology frames the variables required for a given set and the relations between them. Ontologies are created to limit complexity and organize data into information and can thus be used for problem solving.

Table C.5 – Questions to determine the Achievements maturity level 3

ACHIEVEMENTS	ID
Departments of the city council or specific authorised organizations, and private-sector companies build separate platforms or systems to systematically manage resources and data	I3.1
An evaluation of the implementation of GADM initiatives has been carried out	E3
Accessibility of ICT infrastructures in the GADM is improved	I3.2
Data are properly stored, processed and managed in systems and platforms	D3
Accessibility of services that are offered via various channels, such as mobile applications, web portals, service platforms, local community terminals	S3.1
Services and applications are delivered to the public. Application and service operation is monitored and analysed to improve service performance and quality	S3.2
Services are upgraded via functional improvement	S3.3
Application operation is monitored and analysed to improve service performance and quality	S3.4
User satisfaction assessments are conducted periodically	V3

Maturity level 4

The goal that the city needs to meet at this level is to ensure that systems and data are integrated to deliver municipal services. Technologies such as Internet of things (IoT), cloud computing, artificial intelligence (AI) and other advanced technologies may be applied to improve service quality and interoperability. Table C.6 lists the questions used to determine the Achievements maturity level 4.

Table C.6 – Questions to determine the Achievements maturity level 4

ACHIEVEMENTS	ID
Strategy is developed for improving integration and cooperation in the GADM	E4
ICT infrastructure interoperability is achieved	I4.1
Cross-domain[2] ICT infrastructures are provided with interoperability capabilities	I4.2
Cooperation across infrastructures, systems and/or communities is established	I4.3
Cross-domain services and applications are available to the public	S4
Open data are available to the public from different sources as appropriate	D4
Satisfaction assessments of stakeholders and service providers are conducted periodically	V4

Maturity level 5

The goal that the city needs to meet at this level is continual SSC improvement. Each of the city services is studied to determine ways to increase value to citizens while reducing operational costs. It is expected that collaboration among systems, data, innovative services and applications will continuously boost city value creation and citizen's happiness. Enhanced effectiveness and efficiency in city management continue to contribute to the city's long-term SSC vision. Table C.7 lists the questions used to determine the Achievements maturity level 5.

[2] A cross-domain solution (CDS) as a means of information assurance that provides the ability to manually or automatically access or transfer information between two or more differing security domains. They are integrated hardware and software systems that facilitate the transfer of information between incompatible security domains or levels of classification. The goal of a CDS is to allow an isolated critical network to exchange information with others, without introducing the potential for security threats that would normally come with network connectivity.

Table C.7 – Questions to determine the Achievements maturity level 5

ACHIEVEMENTS	ID
Improvement and optimization potential in the GADM is explored	E5
Continuous development of ICT infrastructure is carried out	I5
Improvements on data sharing, utilization and exchange, etc. are made	D5
Services, applications and cooperation based on collaborative systems are continuously improving	S5.1
Continual improvement of services and applications made possible by applying the use of advanced, state-of-the-art technologies	S5.2
Management and operation based on qualitative and quantitative analyses are effectively established	S5.3
Continual improvement of services and applications made possible by applying the use of technologies	S5.4
A systematic assessment process is established to carry out continuous improvement and performance evaluations	V5.1
Results of assessments and evaluations are analysed, and corresponding action plans are implemented as part of the city SSC strategy?	V5.2

KPI value must be filled in the matrix outlined in Table C.8.

Table C.8 – KPI value

No.	Dimension	Sub-dimension	Category	KPI name	Value
1	Economy	ICT	ICT infrastructure	Household Internet access	
2				Fixed broadband subscriptions	
3				Wireless broadband subscriptions	
4				Wireless broadband coverage	
5				Availability of WIFI in public areas	
6			Water and sanitation	Smart water meters	
7				Water supply ICT monitoring	
8			Drainage	Drainage/Storm water system ICT monitoring	
9			Electricity supply	Smart electricity meters	
10				Electricity supply ICT monitoring	
11				Demand response penetration	
12			Transport	Dynamic public transport information	

Table C.8 – KPI value

No.	Dimension	Sub-dimension	Category	KPI name	Value
13				Traffic monitoring	
14				Intersection control	
15			Public sector	Open data	
16				e-Government	
17				Public sector e-procurement	
18		Productivity	Innovation	R&D expenditure	
19				Patents	
20				Small and medium-sized enterprises	
21			Employment	Unemployment rate	
22				Youth unemployment rate	
23				Tourism sector employment	
24				ICT sector employment	
25		Infrastructure	Water and sanitation	Basic water supply	
26				Potable water supply	
27				Water supply loss	
28				Wastewater collection	
29				Household sanitation	
30			Waste	Solid waste collection	
31			Electricity supply	Electricity system outage frequency	
32				Electricity system outage time	
33				Access to electricity	
34			Transport	Public transport network	
35				Public transport network convenience	
36				Bicycle network	
37				Transportation mode share	
38				Travel time index	
39				Shared bicycles	
40				Shared vehicles	
41				Low-carbon emission passenger vehicles	
42			Buildings	Public building	

Table C.8 – KPI value

No.	Dimension	Sub-dimension	Category	KPI name	Value
				sustainability	
43				Integrated building management systems in public buildings	
44			Urban planning	Pedestrian infrastructure	
45				Urban development and spatial planning	
46	Environmental	Environment	Air quality	Air pollution	
47				GHG emissions	
48			Water and sanitation	Drinking water quality	
49				Water consumption	
50				Freshwater consumption	
51				Wastewater treatment	
52			Waste	Solid waste treatment	
53			Environmental quality	EMF exposure	
54				Noise exposure	
55			Public space and nature	Green areas	
56				Green area accessibility	
57				Protected natural areas	
58				Recreational facilities	
59		Energy	Energy	Renewable energy consumption	
60				Electricity consumption	
61				Residential thermal energy consumption	
62				Public building energy consumption	
63	Society and Culture	Education, Health and Culture	Education	Student ICT access	
64				School enrollment	
65				Higher education degrees	
66				Adult Literacy	
67			Health	Electronic health records	
68				Life expectancy	
69				Maternal mortality rate	
70				Physicians	

Table C.8 – KPI value

No.	Dimension	Sub-dimension	Category	KPI name	Value
71				in-patient hospital beds	
72				Health insurance/ Public health coverage	
73			Culture	Cultural expenditure	
74				Cultural infrastructure	
75		Safety, Housing and Social Inclusion	Housing	Informal settlements	
76				Housing expenditure	
77			Social inclusion	Gender income equity	
78				Gini coefficient	
79				Poverty	
80				Voter participation	
81				Child care availability	
82			Safety	Natural disaster related deaths	
83				Disaster related economic losses	
84				Resilience plans	
85				Population living in disaster prone areas	
86				Emergency service response time	
87				Police service	
88				Fire service	
89				Violent crime rate	
90				Traffic fatalities	
91			Food security	Local food production	

C.5.2 Performance matrix

The measured values for each canton (ML1) were stored in an Excel file as shown in Table C.9.

Table C.9 – Measured values for each canton (example)

City/KPI	1	2	3	4	5	…	46	47	48	49	50	…	63	64	65	…	90	91
Cuenca	0.27755	0.11868	69	N/D	21		a) PM10: 33.4 ug/m³, PM2.5: 10.65 ug/m³ b) NO2: 27.7 ug/m³ c) SO2: 4.54 ug/m³ d) O3: 44.57 ug/m³	3,92	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Gualaceo	0.61364	0.3375	153	N/D	0		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Pucará	0.29326	0.13034	73	N/D	0		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D

Table C.9 – Measured values for each canton (example)

City/KPI	1	2	3	4	5	…	46	47	48	49	50	…	63	64	65	…	90	91
El Pan	0.90586	0.51763	226	N/D	0		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Guaranda	0.1324	0.10665	33	N/D	10		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
San Miguel de Bolívar	0.26203	0.17929	66	N/D	0		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Caluma	0.21912	0.17043	55	N/D	30		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	0
Las Naves	0.16155	0.16155	40	N/D	40		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	0.25
Biblián	0.42121	0.13479	105	N/D	8		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	1
Cañar	0.3142	0.12219	79	N/D	6		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
La Troncal	0.17171	0.07285	43	N/D	23		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Déleg	0.5898	0.17694	147	N/D	29		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	0
Mira	0.56813	0.30078	142	N/D	58		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Sigchos	0,2234	0,10311	56	N/D	4		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	0.75
Riobamba	0,19542	0,10756	49	N/D	52		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Chunchi	0,46893	0,2501	117	N/D	0		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	0.3
Guamote	0.10979	0.0549	27	N/D	3		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Pallatanga	0.26065	0.13032	65	N/D	8		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	1
Arenillas	0.25095	0.10755	63	N/D	0		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	0.4
Guayaquil	0.05287	0.03334	13	N/D	225		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Balao	0.12145	0.06073	30	N/D	0		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	0.015
Balzar	0.08629	0.04647	22	N/D	0		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	201.6
Daule	0.15661	0.09442	39	N/D	2		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	0
Coronel Marcelino Maridueña	0.36552	0.18276	91	N/D	30		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Antonio Ante	0.40507	0.16203	101	N/D	15		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	1
Otavalo	0.32754	0.13356	82	N/D	14		a) PM 10 = 26,34; PM 2.5 = 17,29 b) NO2 = 0,00 c) SO2 = 0,00 d) 03 = 0,00	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Pimampiro	0.51247	0.24116	128	N/D	181		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	0.8
Loja	0.17949	0.10069	45	N/D	0		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Macará	0.23681	0.09867	59	N/D	0		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	0.15
Puyango	0.30141	0.07535	75	N/D	6		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	0.3
Babahoyo	0.14605	0.07531	37	N/D	10		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Portoviejo	0.14419	0.09074	36	N/D	10		a) PM10 : 35 ug/m3 en 24 horas PM2.5 NO TENEMOS si se cuenta con monitoreos de b) NO2, c) SO2 Y d) O3 no especifica norma nacional	828,495	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Flavio Alfaro	0.16791	0.10075	42	N/D	0		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	0.6

Table C.9 – Measured values for each canton (example)

City/KPI	1	2	3	4	5	…	46	47	48	49	50	…	63	64	65	…	90	91
Junín	0.12752	0.08502	32	N/D	5		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	0.4
Paján	0.1294	0.07549	32	N/D	5		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Jama	0.12253	0.07658	31	N/D	8		N/D	0,09	N/D	N/D	N/D		N/D	N/D	N/D		N/D	0.92
Logroño	0.52335	0.36635	131	N/D	13		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Tena	0.1465	0.10103	37	N/D	3		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Mera	0.18237	0.15957	46	N/D	6		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Quito	0.17127	0.11375	43	N/D	0		a) PM10=56.5 a) PM2.5=19.9 b) NO2 =28.2 c) SO2 =4.2 d) O3 =	3	N/D	N/D	N/D		N/D	N/D	N/D		N/D	0.1995
Ambato	0.29331	0.15905	73	N/D	9		a) PM10 N/D, PM2.5=5.93 ug/m3 b) 8.09 ug/m3 c)N/D d) 25.59 ug/m3	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Baños de Agua Santa	0.41529	0.25556	104	N/D	8		a) Partículas (PM10 y PM2.5) N/D b)NO2 N/D c) SO2 < 0.055 d) O3 < 0.05	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	1
Mocha	0.49073	0.32715	123	N/D	27		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	0.4
Pelileo	0.28129	0.19151	70	N/D	4		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
San Cristóbal	0.45516	0.24827	114	N/D	0		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Santa Cruz	0.33494	0.13792	84	N/D	0		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	0.5109
Putumayo	0.07451	0.04967	19	N/D	0		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Shushufindi	0.23469	0.13115	59	N/D	0		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	0.8
Cascales	0.15111	0.10074	38	N/D	6		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D
Francisco de Orellana	0.15355	0.07251	38	N/D	0		N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D		N/D	N/D

Each indicator has its rating range divided into five. For each indicator, the following was established:

- Maturity level 1 with the initial measurement.
- Maturity level 5 with the final target.
- Maturity levels 2, 3 and 4 with intermediate targets.

The values (X) for maturity levels (ML) 2, 3, 4 and 5 are presented in Table C.10.

Table C.10 – Ranges for each maturity level

No.	KPI No.	KPI	ML2	ML3	ML4	ML5
1	EC: ICT: ICT: 1C	MINTEL01	0.00% ≤ x < 30%	30% ≤ x < 50.00%	50.00% ≤ x < 80.00%	x ≥ 80.00%
2	EC: ICT: ICT: 2C	MINTEL02	0.00% ≤ x < 30%	30% ≤ x < 50.00%	50.00% ≤ x < 80.00%	x ≥ 80.00%
3	EC: ICT: ICT: 3C	MINTEL03	0 ≤ x < 100	100 ≤ x < 500	500 ≤ x < 1000	x ≥ 1 000
4	EC: ICT: ICT: 4C	MINTEL04	N/D	N/D	N/D	N/D
5	EC: ICT: ICT: 5A	GAD05	0 ≤ x <25	25 ≤ x < 75	75 ≤ x < 150	x ≥ 150
6	EC: ICT: WS: 1C	GAD06	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%

Table C.10 – Ranges for each maturity level

No.	KPI No.	KPI	ML2	ML3	ML4	ML5
7	EC: ICT: WS: 2A	GAD07	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
8	EC: ICT: D: 1A	GAD08	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
9	EC: ICT: ES: 1C	ARCERNNR09	0.00% ≤ x < 5.00%	5.00% ≤ x < 30.00%	30.00% ≤ x < 80.00%	x ≥ 80.00%
10	EC: ICT: ES: 2A	ARCERNNR10	0.00% ≤ x < 5.00%	5.00% ≤ x < 30.00%	30.00% ≤ x < 80.00%	x ≥ 80.00%
11	EC: ICT: ES: 3A	ARCERNNR11	0.00% ≤ x < 1.00%	1.00% ≤ x < 3.00%	3.00% ≤ x < 5.00%	x ≥ 5.00%
12	EC: ICT: T: 1C	GAD12	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
13	EC: ICT: T: 2C	GAD13	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
14	EC: ICT: T: 3A	GAD14	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
15	EC: ICT: PS: 1A	GAD15	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
16	EC: ICT: PS: 2A	GAD16	0 ≤ x < 25	25 ≤ x < 75	75 ≤ x < 150	x ≥ 150
17	EC: ICT: PS: 3A	GAD17	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
18	EC: P: IN: 1C	GAD18	0.00% ≤ x < 0.01%	0.01% ≤ x < 0.02%	0.02% ≤ x < 0.05%	x ≥ 0.05%
19	EC: P: IN: 2C	SENADI19	N/D	N/D	N/D	N/D
20	EC: P: IN: 3A	MPCEIP20	N/D	N/D	N/D	N/D
21	EC: P: EM: 1C	MDT21 – INEC21	N/D	N/D	N/D	N/D
22	EC: P: EM: 2C	MDT22 – INEC22	N/D	N/D	N/D	N/D
23	EC: P: EM: 3A	MDT23 – INEC23	N/D	N/D	N/D	N/D
24	EC: P: EM: 4A	MDT24 – INEC24	N/D	N/D	N/D	N/D
25	EC: I: WS: 1C	GAD25	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
26	EC: I: WS: 2C	GAD26	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
27	EC: I: WS: 3C	GAD27	x ≥ 40.00%	40.00% < x ≤ 25.00%	25.00% < x ≤ 11.00%	x < 11.00%
28	EC: I: WS: 4C	GAD28	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
29	EC: I: WS: 5C	GAD29	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
30	EC: I: WA: 1C	GAD30	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
31	EC: I: ES: 1C	ARCERNNR31	N/D	N/D	N/D	N/D
32	EC: I: ES: 2C	ARCERNNR32	N/D	N/D	N/D	N/D
33	EC: I: ES: 3C	ARCERNNR33	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
34	EC: I: T: 1C	GAD34	0 ≤ x < 50	50 ≤ x < 100	100 ≤ x < 150	x ≥150
35	EC: I: T: 2A	GAD35	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
36	EC: I: T: 3C	GAD36	0 ≤ x < 5	5 ≤ x < 10	10 ≤ x < 15	x ≥ 15
37	EC: I: T: 4A	GAD37	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
38	EC: I: T: 5A	GAD38	x ≥ 1.75	1.75 < x <= 1.45	1.45 < x ≤ 1.15	x < 1.15
39	EC: I: T: 6A	GAD39	0 ≤ x < 100	100 ≤ x < 500	500 ≤ x < 1 000	x ≥ 1 000
40	EC: I: T: 7A	GAD40	0 ≤ x < 50	50 ≤ x < 250	250 ≤ x < 500	x ≥ 500
41	EC: I: T: 8A	GAD41	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
42	EC: I: B: 1A	GAD42	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
43	EC: I: B: 2A	GAD43	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
44	EC: I: UP: 1A	GAD44	0.00% ≤ x < 6.00%	6.00% ≤ x < 10.00%	10.00% ≤ x < 14.00%	x ≥ 14.00%
45	EC: I: UP: 2A	GAD45	NO	PARCIAL	SI	PLANIFICADA
46	EN: EN: AQ: 1C	GAD46	1 o 2 mediciones	3 mediciones	4 mediciones	5 mediciones
47	EN: EN: AQ: 2C	GAD47	x ≥ 14.8	14.8 < x ≤ 6.7	6.7 < x ≤ 2.4	x < 2.4
48	EN: EN: WS: 1C	GAD48	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
49	EN: EN: WS: 2C	GAD49	x ≥ 300	300 < x ≤ 200	200 < x ≤ 100	x < 100

Table C.10 – Ranges for each maturity level

No.	KPI No.	KPI	ML2	ML3	ML4	ML5
50	EN: EN: WS: 3C	GAD50	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
51	EN: EN: WS: 4C	GAD51	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
52	EN: EN: WA: 1C	GAD52	b es mayor o d es mayor	c es mayor	e es mayor	a es mayor
53	EN: EN: EQ: 1C	GAD53	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
54	EN: EN: EQ: 2A	GAD54	x ≥ 40.00%	40.00% < x ≤ 23.00%	23% < x ≤ 6.00%	x < 6.00%
55	EN: EN: PSN: 1C	GAD55	0 ≤ x < 70	70 ≤ x < 100	100 ≤ x < 139	x ≥ 139
56	EN: EN: PSN: 2A	GAD56	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
57	EN: EN: PSN: 3A	GAD57	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
58	EN: EN: PSN: 4A	GAD58	0 ≤ x < 700	700 ≤ x < 1000	1000 ≤ x < 1390	x ≥ 1390
59	EN: E: E: 1C	ARCERNNR59	0.00% ≤ x < 5.00%	5.00% ≤ x < 30.00%	30.00% ≤ x < 80.00%	x ≥ 80.00%
60	EN: E: E: 2C	ARCERNNR60	x ≥ 10500	10500 < x ≤ 5690	5690 < x ≤ 2310	x < 2310
61	EN: E: E: 3C	ARCERNNR61	0.00% ≤ x < 5.00%	5.00% ≤ x < 30.00%	30.00% ≤ x < 80.00%	x ≥ 80.00%
62	EN: E: E: 4A	GAD62	x ≥ 43.20	43.20 < x ≤ 17.70	17.70 < x ≤ 6.05	x < 6.05
63	SC: EH: ED: 1C	MINEDUC63	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
64	SC: EH: ED: 2C	MINEDUC64	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% ≤ x < 85.00%	x ≥ 85.00%
65	SC: EH: ED: 3C	SENESCYT65	N/D	N/D	N/D	N/D
66	SC: EH: ED: 4C	MINEDUC66	N/D	N/D	N/D	N/D
67	SC: EH: ED: 5A	MSP67	N/D	N/D	N/D	N/D
68	SC: EH: H: 1C	INEC68	N/D	N/D	N/D	N/D
69	SC: EH: H: 2C	INEC69	N/D	N/D	N/D	N/D
70	SC: EH: H: 3C	MSP70	N/D	N/D	N/D	N/D
71	SC: EH: H: 4A	MSP71	N/D	N/D	N/D	N/D
72	SA: EH: H: 5A	MSP72	N/D	N/D	N/D	N/D
73	SA: EH: C: 1C	GAD73	0.00% ≤ x < 1.00%	1.00% ≤ x < 4.00%	4.00% ≤ x < 7.00%	x ≥ 7.00%
74	SC: EH: C: 2A	GAD74	0 <= x < 7	7 ≤ x < 14	14 ≤ x <21	x ≥ 21
75	SC: SH: HO: 1C	GAD75	x ≥ 45.50%	45.50% < x ≤ 27.50%	27.50% < x ≤ 16.70%	x < 16.70%
76	SC: SH: HO: 2A	GAD76	x ≥ 30.00%	30.00% < x ≤ 25.00%	25.00% < x ≤ 20.00%	x < 20.00%
77	SC: SH: SI: 1C	GAD77 - INEC77	0 ≤ x < 0.5	0.5 ≤ x < 0.7	0.7 ≤ x <0.8	x ≥ 0.8
78	SC: SH: SI: 2C	GAD78	x ≥ 0.437	0.437 < x ≤ 0.397	0.397 < x ≤ 0.364	x < 0.364
79	SC: SH: SI: 3C	GAD79- INEC79	x ≥ 50.40%	50.40% < x ≤ 28.9%	28.90% < x ≤ 17.00%	x < 17.00%
80	SC: SH: SI: 4C	CNE80	N/D	N/D	N/D	N/D
81	SC: SH: SI: 5A	MIES81	N/D	N/D	N/D	N/D
82	SC: SH: SA: 1C	SNGRE82	x ≥ 100	100 < x ≤ 50	50 < x ≤ 10	x < 10
83	SC: SH: SA: 2C	SNGRE83	N/D	N/D	N/D	N/D
84	SC: SH: SA: 3A	SNGRE84	x ≤ 2	x = 3	x = 4	x = 5
85	SC: SH: SA: 4A	SNGRE85	N/D	N/D	N/D	N/D
86	SC: SH: SA: 5A	ECU86	x ≤ 0:20:00	0:20:00 < x ≤ 0:15:00	0:15:00 < x ≤ 0:10:00	x < 0:10:00
87	SC: SH: SA: 6C	MG87	N/D	N/D	N/D	N/D
88	SC: SH: SA: 7C	GAD88	0 ≤ x < 100	100 ≤ x < 130	130 ≤ x < 160	x ≥ 160
89	SC: SH: SA: 8C	MG89	N/D	N/D	N/D	N/D
90	SC: SH: SA: 9C	ANT90	x ≥ 45	45 < x ≤ 30	30 < x ≤ 15	x < 15
91	SC: SH: FS: 1A	GAD91	0.00% ≤ x < 25.00%	25.00% ≤ x < 55.00%	55.00% < x < 85.00%	x ≥ 85.00%

C.5.3 Maturity assessment

According to the responses to the Maturity Level Survey, the maturity level value is obtained for each achievement, see Table C.11.

Year 2020

Table C.11 – Maturity level by achievements, year 2020

Canton	Strategy	Infrastructure	Data	Services and applications	Evaluation
Quito	3.33	4.67	5.00	4.00	4.00
Ambato	5.00	4.33	4.00	3.00	5.00
Portoviejo	4.67	4.50	5.00	4.00	4.00
Riobamba	5.00	4.50	4.00	3.75	0.00
Cuenca	2.33	4.67	3.00	4.75	0.50
Babahoyo	5.00	3.67	4.00	3.25	3.00
Cañar	3.67	3.83	3.00	1.75	3.00
Antonio Ante	4.00	3.33	3.00	1.75	1.50
Guayaquil	3.67	4.67	2.00	4.75	1.00
Pimampiro	3.67	0.33	3.00	4.50	2.00
Arenillas	3.33	2.50	4.00	1.00	1.00
Jama	3.67	0.67	2.00	2.75	0.50
Biblián	3.00	2.00	2.00	1.50	0.00
Sigchos	4.00	1.83	1.00	3.50	0.50
Baños de Agua Santa	1.33	2.33	2.00	1.50	1.00
Déleg	3.33	1.83	2.00	1.00	1.00
Caluma	4.67	1.00	2.00	3.25	0.00
Daule	2.33	2.50	1.00	3.00	1.00
Macará	2.00	2.33	3.00	1.50	0.00
La Troncal	1.00	2.00	4.00	1.75	2.50
Balao	2.00	2.00	1.00	2.50	0.00
Otavalo	2.00	1.33	2.00	3.25	0.00
Guaranda	2.00	0.83	1.00	1.25	1.00
San Cristóbal	1.00	2.33	2.00	2.00	0.00
Pucará	1.33	3.00	0.00	1.25	0.00
Chunchi	2.00	0.50	1.00	2.25	0.00
Pallatanga	1.00	0.50	2.00	1.50	1.00
Pelileo	2.33	0.50	1.00	1.25	0.00
Gualaceo	2.00	0.50	2.00	1.75	1.00
Balzar	1.33	0.50	1.00	0.00	1.00
Putumayo	1.00	0.00	1.00	2.00	0.00
Coronel Marcelino Maridueña	2.00	1.00	1.00	0.25	0.00
Guamote	2.00	1.83	1.00	1.00	1.00
Mira	0.00	1.00	2.00	1.50	0.00
Santa Cruz	0.00	1.00	1.00	0.25	0.00
Cascales	0.00	0.50	2.00	0.50	0.00

Table C.11 – Maturity level by achievements, year 2020

Canton	Strategy	Infrastructure	Data	Services and applications	Evaluation
Shushufindi	0.00	0.00	1.00	0.00	0.00
Tena	0.00	1.00	0.00	0.50	0.00
Junín	0.00	0.00	0.00	0.00	0.00
Francisco de Orellana	0.33	0.50	1.00	1.25	0.00
Paján	1.67	1.50	1.00	0.00	0.00
Loja	1.33	1.50	0.00	1.25	0.00
San Miguel de Bolívar	0.00	0.00	1.00	0.00	0.00
Flavio Alfaro	0.00	0.00	0.00	0.00	0.00
Logroño	0.00	0.00	0.00	0.00	0.00
Puyango	0.00	0.00	0.00	0.00	0.00
Mocha	1.00	0.00	0.00	0.00	0.00
Las Naves	0.00	0.00	0.00	0.00	0.00
El Pan	0.00	0.50	1.00	0.00	0.00
Mera	0.00	0.50	1.00	0.00	0.00

C.5.4 Statistical calculation

The procedure to rank the maturity level of Ecuador's smart sustainable cities included the following:

1) Only the 50 cantons that completed both the maturity level survey and the KPI matrix were considered.

2) For the survey, achievements were evaluated in the following areas:
   - Strategy (5 points)
   - Infrastructure (5 points)
   - Data (5 points)
   - Services and applications (5 points)
   - Evaluation (5 points).

3) In the year 2020: The final score for the survey was the average of all the achievement scores. This point was omitted in the year 2022.

4) A total of 62 indicators were evaluated: 45 provided by GADMs; and 17 by institutions in the year 2020. A total of 60 indicators were evaluated: 52 provided by GADMs; and 18 by institutions in the year 2022:
   - No canton submitted information for all 45 indicators.
   - It was not possible to gather information for 29 indicators from institutions.
   - A quality control was performed on the reported data and those deemed to contain inconsistencies were marked as "not available" (N/A).

5) For each indicator, the following was established:
   - Maturity level 1 with the initial measurement.
   - Maturity level 5 with the final target.
   - Maturity levels 2, 3 and 4 with intermediate targets.

6) The maturity level of each KPI was obtained for every canton.

7) The final KPI value was the average of all individual KPI scores.

8) The overall score is the sum of the final survey and KPI scores. This point was omitted in the year 2022.

9) The average maturity level is obtained by dividing the overall score by two. This point was omitted in the year 2022.

10) Finally, the rankings are established by listing the overall score for each canton from highest to lowest. This point was omitted in the year 2022.

C.5.5 Data collection

The maturity level data was collected through an online evaluation survey.

The KPI data was filled in a KPI matrix, it was necessary to validate the quality of the data because only 16 municipalities delivered the document with the process of obtaining the KPI values.

All data is stored in an Excel file to which a small automation has been added that graphs for the canton that is selected the results obtained and their respective recommendations to be smart sustainable city or community.

C.5.6 Transparency

At present the results have been shared with the 50 municipalities, the Universidad Andina Simón Bolívar and the Instituto de Altos Estudios Nacionales. In the future they will be published as Open Data. The results of the measurement are published in the Open Data Portal of the Republic of Ecuador https://datosabiertos.gob.ec/dataset/nivel-de-madurez-ciudades-inteligentes-y-sostenibles.

C.6 Results

C.6.1 Evaluation and roadmap

The results obtained allow the creation of a personalized *Good Practice Guide* for the canton. In this guide, it is recommended to measure the baseline of the indicators for which no information is available, to advance to the next level of maturity based on the score obtained and to meet the specified achievements for its path to becoming a Smart sustainable city or community.

In the future, an individual analysis of each indicator can be carried out at national level, taking into account the data at the urban and rural level.

The results of the maturity level survey for the year 2020 in graphical form are presented in Figures C.4 to C.8.

Strategy

An upward curve can be seen in the achievement of levels 1 to 5, contrary to what is suggested in [ITU-T Y.4904]. In order to achieve the next level, the previous level must be fully completed; therefore, most GADMs must first work to define their SSC strategy (Maturity level 1).

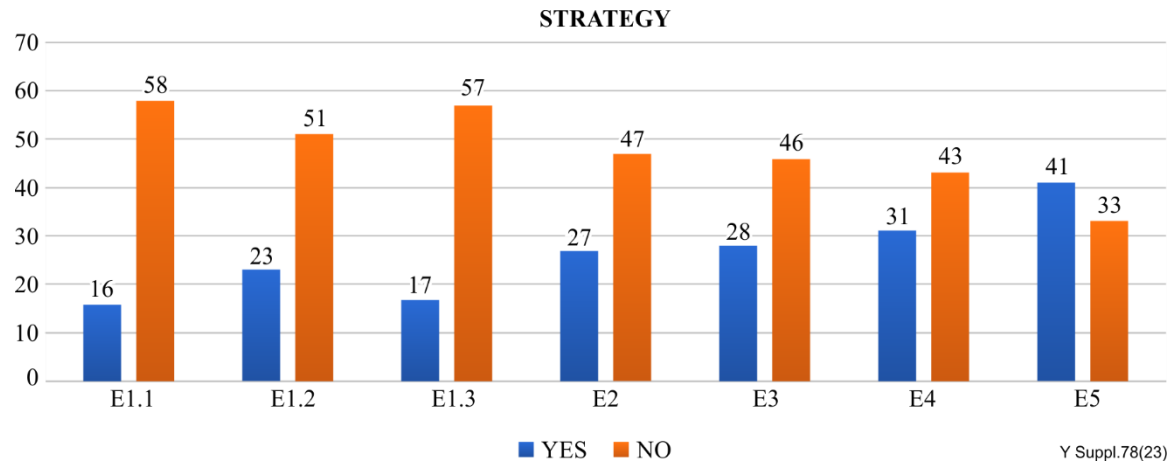

Figure C.4 – Strategy

Infrastructure

An upward curve can be seen in the achievement of levels 2 and 3, contrary to what is suggested in [ITU-T Y.4904]. In order to achieve the next level, the previous level must be fully completed; therefore, most GADMs must first work to implement basic SSC infrastructure (Maturity level 1).

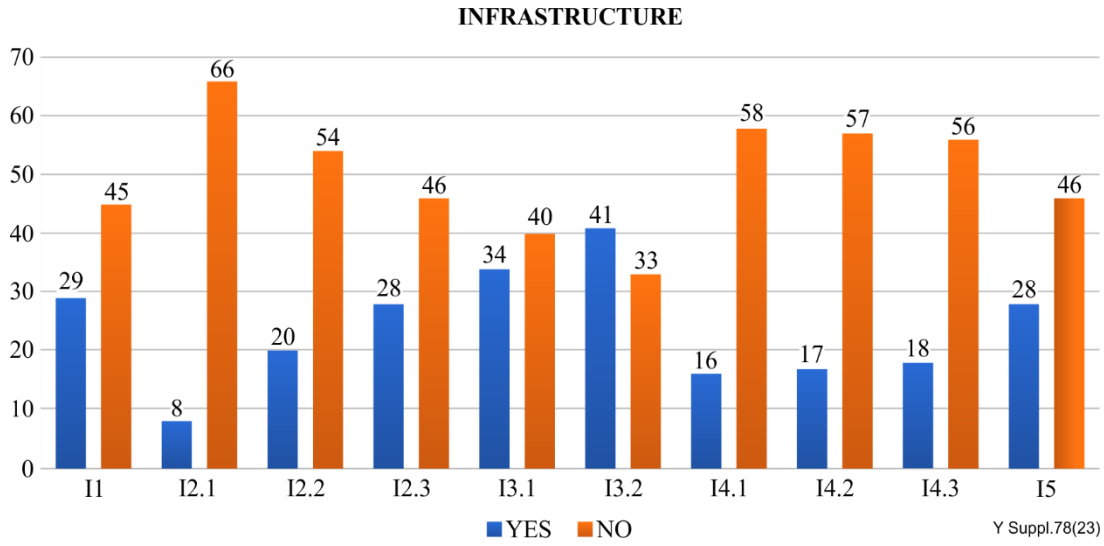

Figure C.5 – Infrastructure

Data

A high value can be seen for level 3, contrary to what is suggested in [ITU-T Y.4904]. In order to achieve the next level, the previous level must be fully completed; therefore, most GADMs must first work to define their open data and respective data sets (Maturity levels 1 and 2).

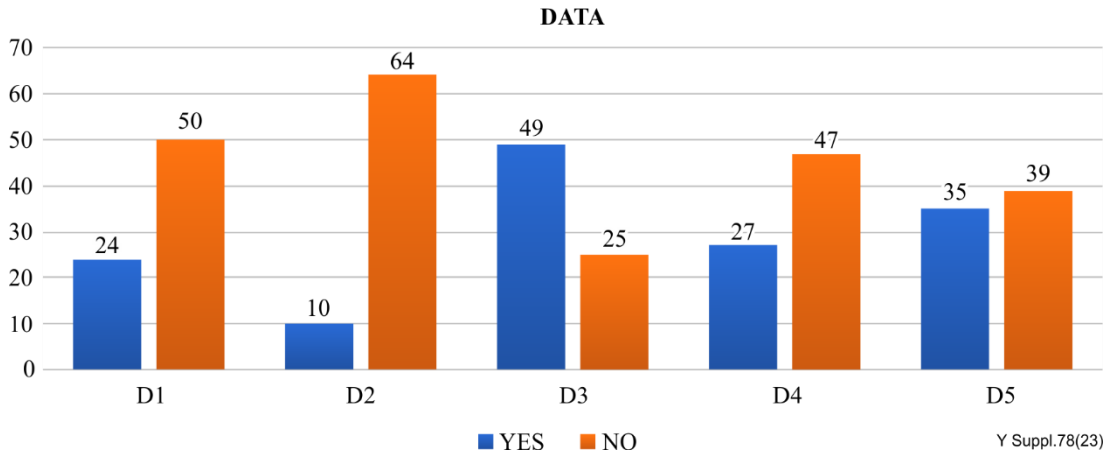

Figure C.6 – Data

Services and applications

A downward curve can be seen from levels 1 to 4, in line with what is suggested in [ITU-T Y.4904]. In order to achieve the next level, the previous level must be fully completed; therefore, most GADMs must first establish an inventory of services, prioritize them according to citizen impact, associate them with respective applications and make them available to the public.

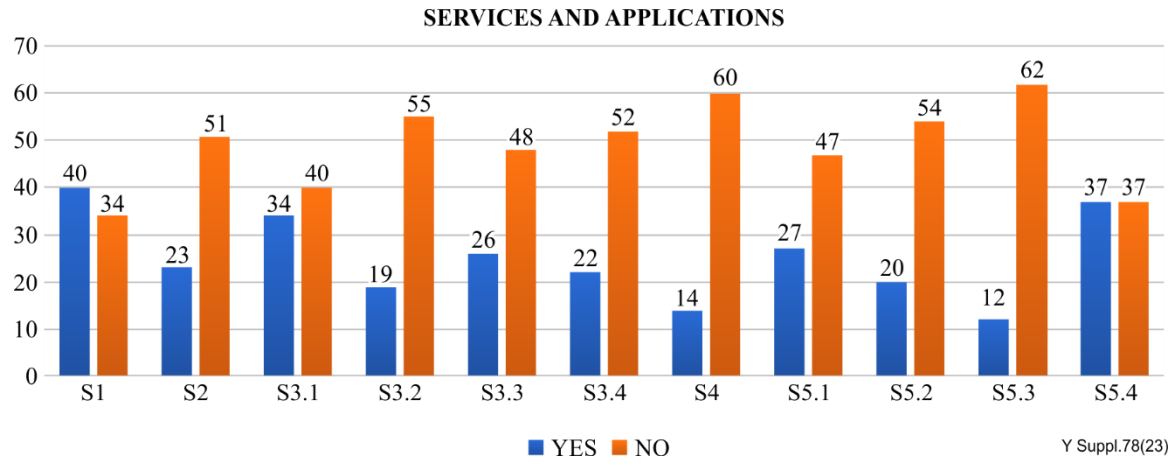

Figure C.7 – Services and applications

Evaluation

Achievements in terms of evaluation have been low, based on the results of the survey. This is an area, therefore, that requires more work from the GADMs.

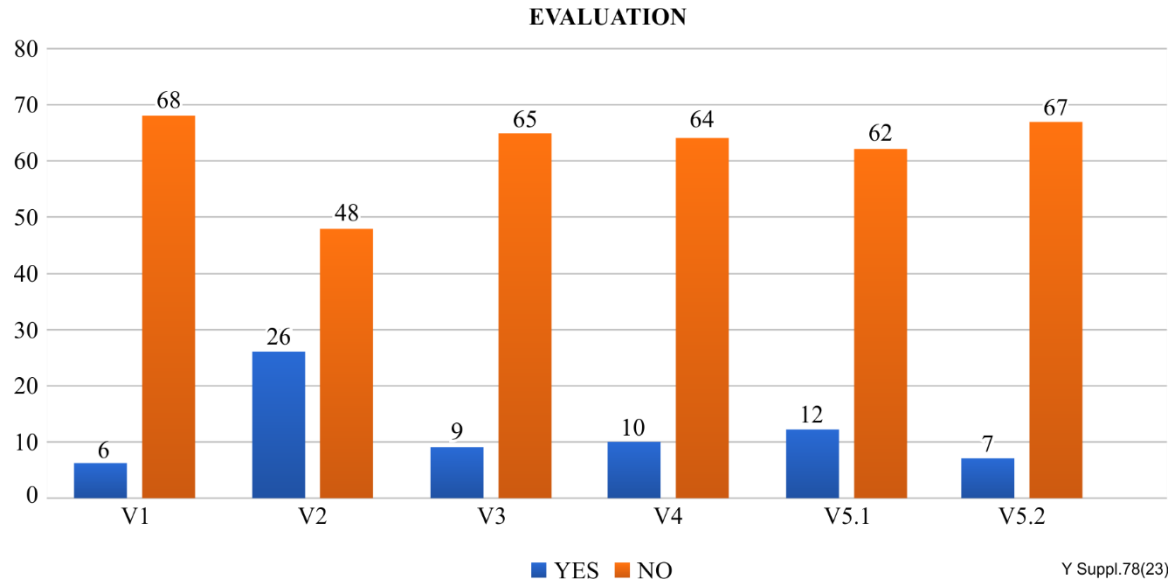

Figure C.8 – Evaluation

Key performance indicators (KPIs)

Economic dimension

Figure C.9 shows the economic indicators with scoring out of five for economic indicators, sorted in descending order, for the 50 GADMs that completed the KPI matrix.

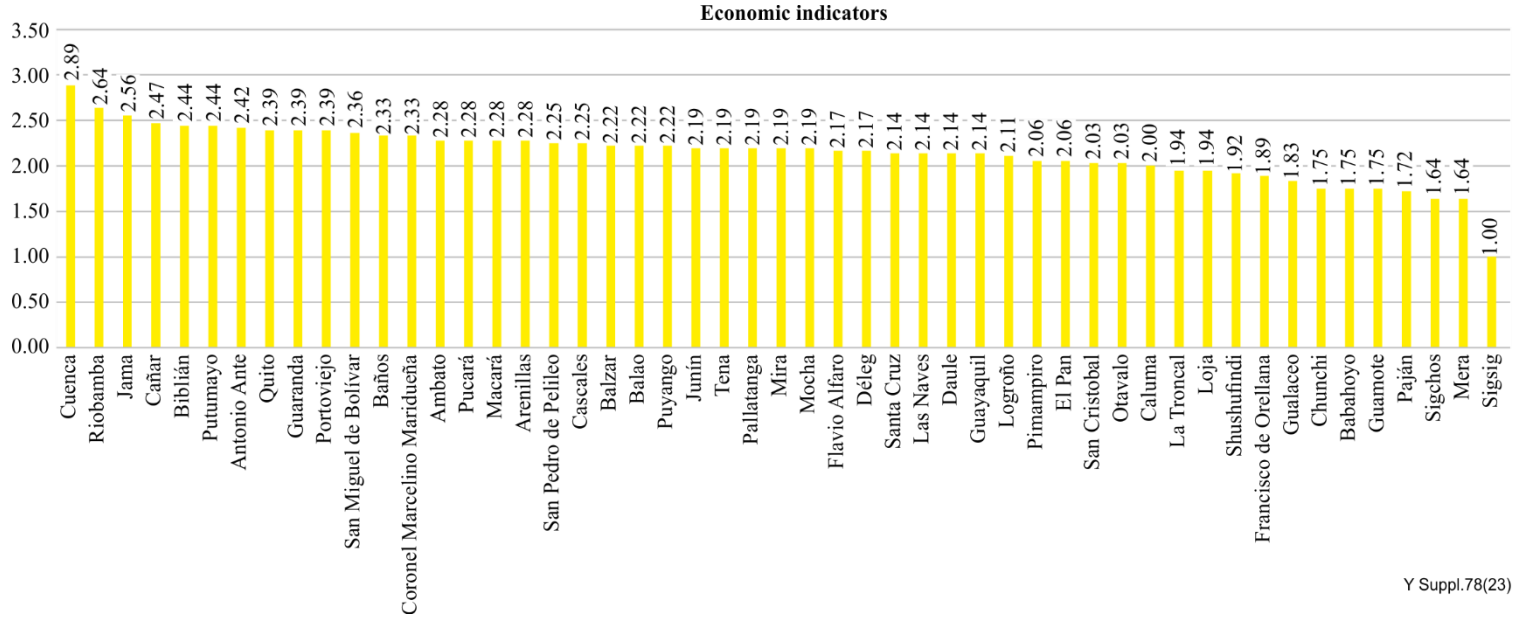

Figure C.9 – Economic indicators

Environmental dimension

Figure C.10 shows the environmental indicators with scoring out of five for environmental indicators, sorted in descending order, for the 50 GADMs that completed the KPI matrix.

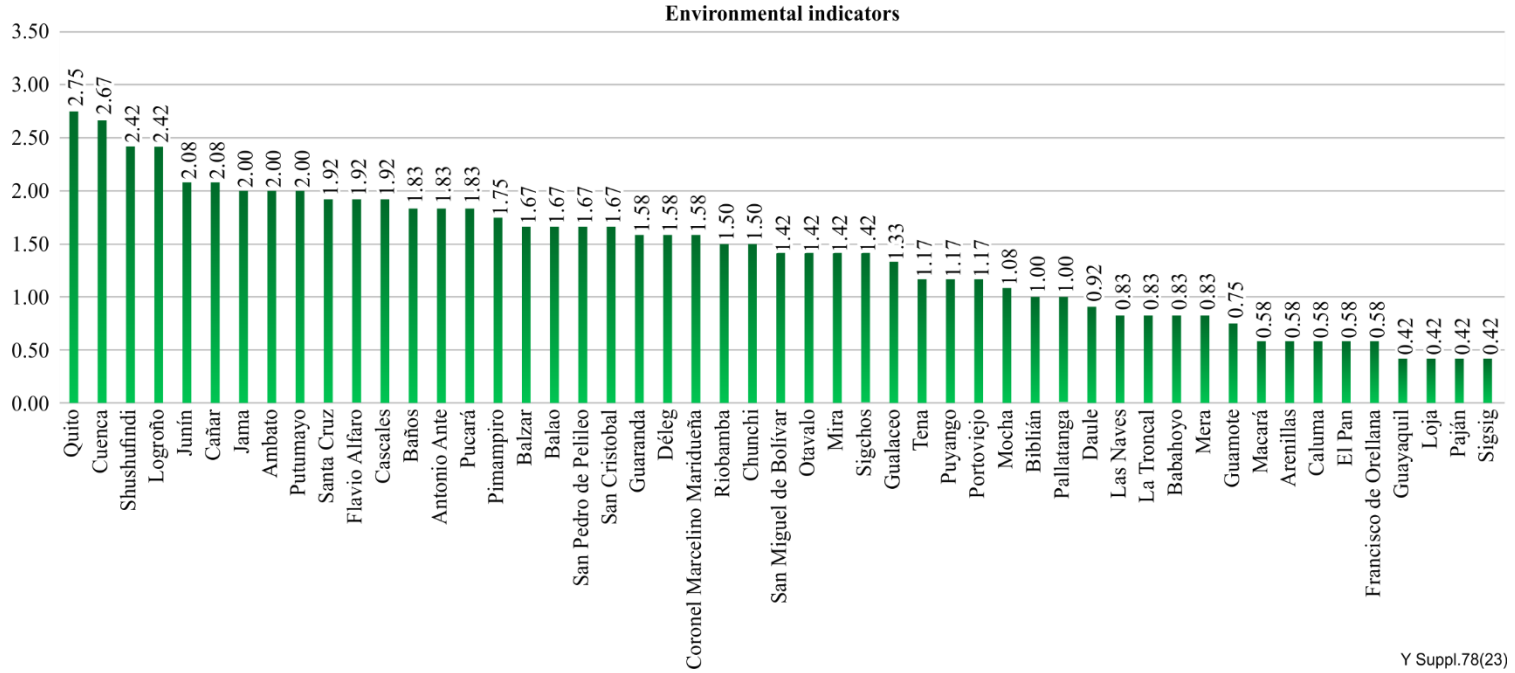

Figure C.10 – Environmental indicators

Sociocultural dimension

Figure C.11 shows the sociocultural indicators with scoring out of five for sociocultural indicators, sorted in descending order, for the 50 GADs that completed the KPI matrix.

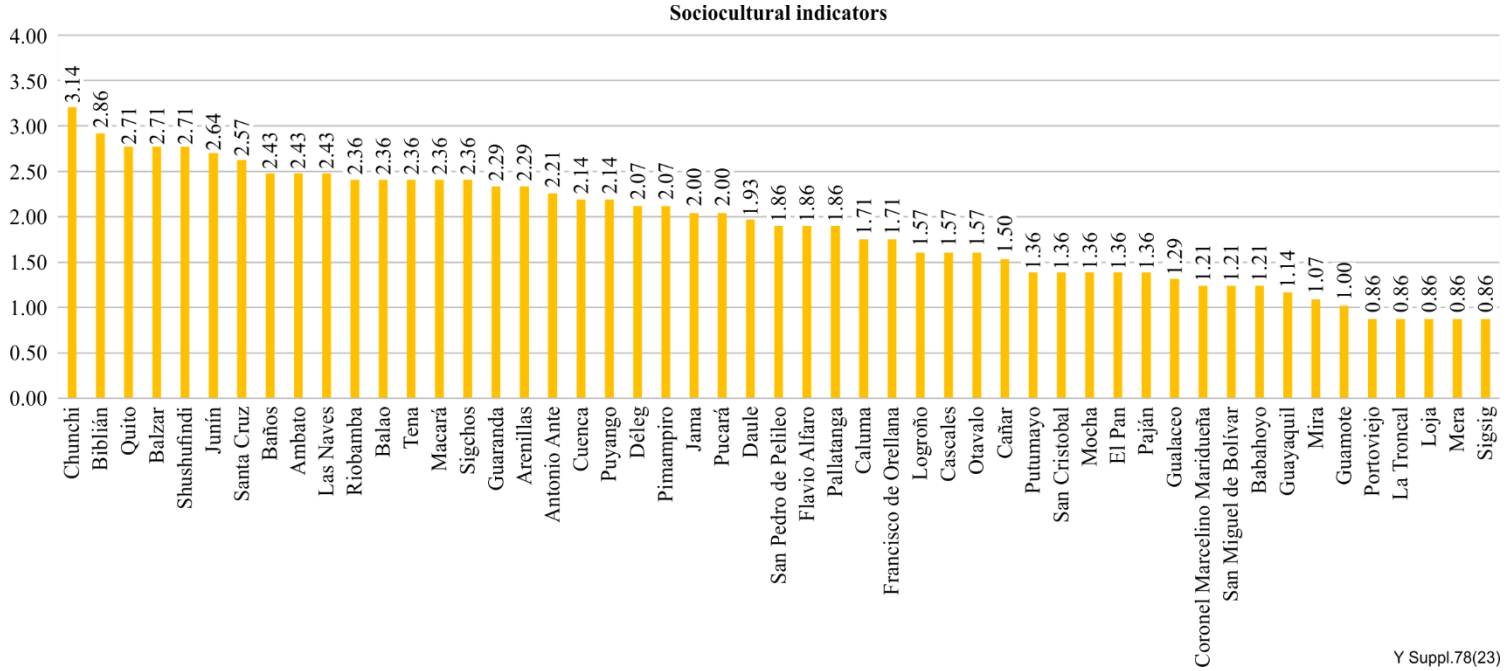

Figure C.11 – Sociocultural indicators

Overview

Figure C.12 shows the final summary with combined scores based on survey and KPIs (both out of five), sorted in descending order, for the 50 GADMs that completed the KPI matrix.

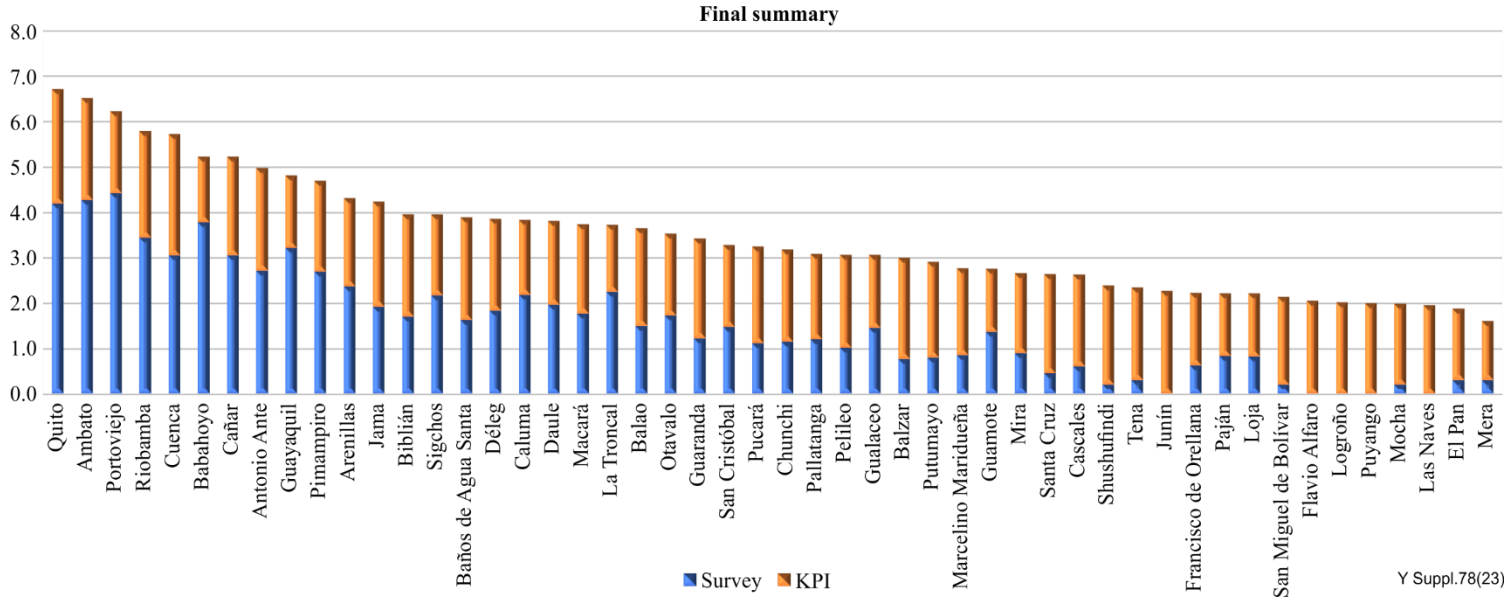

Figure C.12 – Final summary

Table C.12 shows the ranking from 2020.

Table C.12 – Ranking 2020

Ranking	Canton	Survey	KPI	Total	Average maturity level
1	Quito	4.20	2.53	6.73	3.37
2	Ambato	4.27	2.26	6.52	3.26
3	Portoviejo	4.43	1.81	6.24	3.12
4	Riobamba	3.45	2.35	5.80	2.90
5	Cuenca	3.05	2.68	5.73	2.86
6	Babahoyo	3.78	1.45	5.23	2.62
7	Cañar	3.05	2.18	5.23	2.61
8	Antonio Ante	2.72	2.26	4.97	2.49
9	Guayaquil	3.22	1.60	4.81	2.41
10	Pimampiro	2.70	2.00	4.70	2.35
11	Arenillas	2.37	1.95	4.32	2.16
12	Jama	1.92	2.32	4.24	2.12
13	Biblián	1.70	2.26	3.96	1.98
14	Sigchos	2.17	1.79	3.96	1.98
15	Baños de Agua Santa	1.63	2.26	3.89	1.95
16	Déleg	1.83	2.03	3.87	1.93
17	Caluma	2.18	1.66	3.84	1.92
18	Daule	1.97	1.85	3.82	1.91
19	Macará	1.77	1.97	3.73	1.87
20	La Troncal	2.25	1.48	3.73	1.87
21	Balao	1.50	2.15	3.65	1.82
22	Otavalo	1.72	1.81	3.52	1.76
23	Guaranda	1.22	2.21	3.43	1.71
24	San Cristóbal	1.47	1.81	3.27	1.64
25	Pucará	1.12	2.13	3.25	1.62
26	Chunchi	1.15	2.03	3.18	1.59
27	Pallatanga	1.20	1.89	3.09	1.54
28	Pelileo	1.02	2.05	3.07	1.53
29	Gualaceo	1.45	1.61	3.06	1.53
30	Balzar	0.77	2.23	2.99	1.50
31	Putumayo	0.80	2.11	2.91	1.46
32	Marcelino Maridueña	0.85	1.92	2.77	1.38
33	Guamote	1.37	1.39	2.75	1.38
34	Mira	0.90	1.76	2.66	1.33
35	Santa Cruz	0.45	2.19	2.64	1.32
36	Cascales	0.60	2.03	2.63	1.32
37	Shushufindi	0.20	2.19	2.39	1.20
38	Tena	0.30	2.05	2.35	1.17
39	Junín	0.00	2.27	2.27	1.14
40	Francisco de Orellana	0.62	1.61	2.23	1.11
41	Paján	0.83	1.39	2.22	1.11
42	Loja	0.82	1.40	2.22	1.11
43	San Miguel de Bolívar	0.20	1.94	2.14	1.07
44	Flavio Alfaro	0.00	2.05	2.05	1.02
45	Logroño	0.00	2.02	2.02	1.01
46	Puyango	0.00	2.00	2.00	1.00
47	Mocha	0.20	1.79	1.99	1.00
48	Las Naves	0.00	1.95	1.95	0.98
49	El Pan	0.30	1.58	1.88	0.94
50	Mera	0.30	1.31	1.61	0.80

Table C.13 shows the results obtained in 2022.

Table C.13 – Results 2022

Canton	Maturity level by achievements [ITU-T Y.4904]	Maturity level by KPI [ITU-T Y.4903]	Measured KPI
CUENCA	5.00	3.63	60
AMBATO	4.80	3.55	49
QUITO	4.10	3.54	52
RIOBAMBA	5.00	3.49	45
PORTOVIEJO	4.37	3.49	43
SAN CRISTOBAL	1.35	3.46	35
LOJA	2.17	3.42	50
DAULE	1.98	3.38	39
GUAYAQUIL	2.53	3.38	8
BAÑOS	1.83	3.38	8
EL CHACO	0.98	3.38	8
TULCAN	2.20	3.33	12
IBARRA	2.77	3.25	8
SANTA ANA	1.80	3.25	8
MUISNE	1.07	3.25	8
CHAMBO	0.87	3.25	8
BOLIVAR - MANABI	0.75	3.22	45
MANTA	4.27	3.21	47
PEDRO VICENTE MALDONADO	3.87	3.20	30
TAISHA	0.50	3.19	31
MACHALA	1.13	3.19	26
JUNIN	0.00	3.18	49
GUANO	2.62	3.18	44
CHONE	2.73	3.16	49
EL PANGUI	0.00	3.13	39
URBINA JADO (SALITRE)	2.32	3.13	8
PIÑAS	0.70	3.12	52
ARAJUNO	0.00	3.08	24
BIBLIAN	0.87	3.08	37
MORONA	1.98	3.08	51
GUARANDA	1.03	3.07	27
VENTANAS	0.88	3.06	32
COTACACHI	2.58	3.06	51
PUTUMAYO	2.18	3.00	34
PASAJE	0.00	3.00	36
SANTO DOMINGO	0.00	3.00	35
SANTA CLARA	2.80	2.98	50
ALAUSI	1.68	2.95	38
EL EMPALME	0.00	2.94	18
PINDAL	0.45	2.92	36
SANTA CRUZ	0.00	2.91	23

Table C.13 – Results 2022

Canton	Maturity level by achievements [ITU-T Y.4904]	Maturity level by KPI [ITU-T Y.4903]	Measured KPI
CHORDELEG	0.52	2.90	30
SANTA ISABEL	1.38	2.89	38
PALENQUE	0.00	2.89	36
EL CARMEN	4.23	2.89	35
PALTAS	1.38	2.88	8
LA MANA	0.00	2.86	37
ISIDRO AYORA	0.00	2.86	37
MERA	0.20	2.86	36
SALCEDO	1.05	2.84	38
QUINSALOMA	1.05	2.83	12
QUEVEDO	2.25	2.81	32
VALENCIA	2.15	2.74	38
CHINCHIPE	0.40	2.73	33
SHUSHUFINDI	1.32	2.71	17
ARCHIDONA	1.20	2.70	23
CAMILO PONCE ENRIQUEZ	0.27	2.63	16
MONTALVO	1.27	2.57	42
BALAO	0.00	2.44	16
SAN MIGUEL	0.00	2.41	29

C.6.2 Opportunities to use the SSC-MM

Critical contextualization opportunity

The establishment of smart sustainable cities and communities contributes to the attainment of Sustainable Development Goal 11, which is to "make cities and human settlements inclusive, safe, resilient and sustainable".

Cities are hotbeds of ideas, commerce, culture, science, productivity, social development and much more. At their best, cities have enabled people's social and economic development. In recent decades, the world has experienced unprecedented urban growth. In 2015, nearly 4 billion people were living in cities and that number is expected to grow to 5 billion by 2030. Consequently, urban planning and management needs to be improved to make the world's urban spaces more inclusive, safe, resilient and sustainable.

Maintaining cities in such a way that they continue to generate jobs and prosperity, without placing undue pressure on land and resources, poses a great many challenges. Typically, cities encounter problems of congestion, shortage of funds for basic services, lack of appropriate land and housing policies and deteriorating infrastructure.

The problems that cities face, such as the safe collection and management of solid waste, can be overcome in ways that allow the cities to continue to thrive and grow, while making better use of resources and reducing pollution and poverty. An example of this is increasing municipal waste collection services. The future that we are striving for includes cities rich in opportunity, with access to basic services, energy, housing, transport and more facilities for all.

The data that each city generates must be made open and available to society. The potential of open data can improve services, optimize processes and lead to solutions for different challenges.

The analysis of data generated by cities is a major resource for countries in overcoming challenging times. Data analysis is crucial to the establishment of public policies for health, security, mobility, employment, basic services, etc.

Opportunity for alignment with the international community

Keeping the parameters to be evaluated included in [ITU-T Y.4903] and [ITU-T Y.4904] almost 100% allows comparison with other cities that comply with this standard.

It is important to highlight the diversity of realities of each canton, for example we can say that there are 221 cantons in Ecuador, and therefore 221 realities.

Challenges to use of the SSC-MM

Contextualization challenge of an international model

The main challenge is to increase the number of cities participating in this initiative, having done so with 50 of the 221 Ecuadorian cantons allows us to share this experience of implementing the ITU-T Y.4000-series Recommendations, and strengthens us to replicate this work. Templates, calculation formulas, surveys, matrices and other developed materials will allow the project to be replicated in other locations in the future.

Data and information identification and capture challenge

The challenge of obtaining all the data for the case of Ecuador is extremely ambitious, we must have about 28000 data if all municipalities are reached. Data validation is essential, because despite having documents with templates for calculations, they were not always applied in the same way and it was necessary to consult with municipalities as to why several values were reported.

Metrification challenge for different indicators

It is important to note that a point could not be established that separates general data from urban and rural information.

C.7 Conclusion

The Ministry of Telecommunications and the Information Society of Ecuador carried out in 2020 the measurement of the maturity level of smart Sustainable cities applying [ITU-T Y.4903] and [ITU-T Y.4904]. The values to determine the maturity level of each KPI were obtained after analysing the information collected from the 50 participating cities. In order to make it comparable, the Wi-Fi point indicator was adjusted by calculating it per 100 000 inhabitants.

The primary sources of information are divided between municipalities and public entities. The 91 KPIs were not measured, up to 67 KPIs per city were measured. The objective of the measurement is not to encourage competition between cities, but rather to make known what their reality is on the way to becoming a smart sustainable city.

After the evaluation, a *Manual of Good Practices in Smart and Sustainable Cities* was generated and personalized for each of the municipalities, this manual was delivered to the Mayors of the municipalities.

In this manual, for each city, the results of both the survey and the KPIs are collected, and based on a colour code, the topics to be implemented, measured, maintained, or improved are indicated.

Since 2022 it is planned to execute the measurement with a periodicity of 1 year, in order to analyse the sharing of cities to become smart and sustainable.

C.8 References

[b-U4SSC] *U4SSC Collection Methodology for Key Performance Indicators for Smart Sustainable Cities, United for Smart Sustainable Cities*.

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