Construction of Smart City Development Index in Indonesia

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Abstract. Development in urban areas requires city management to solve problems that occur because of high population growth. The complexity of the issues in urban areas varies widely, including a decrease in the quality of public services, reduced availability of residential land, congestion on the highway, excessive energy consumption, waste accumulation, increased crime rates, and other social problems. City assessment tools can be used as support for decision-making in urban development as they provide assessment methodologies for cities to show progress towards defined targets. In the 21st century, there has been a shift from sustainability assessment to developing smart cities. The construction of the Smart City Development Index (SCDI) is considered capable of providing a basis for formulating effective and efficient solutions in reducing existing city problems. The purpose of this study is to find out the general description and get the factors that form SCDI; get the results of SCDI measurements; examine the uncertainty analysis and sensitivity analysis of SCDI, and see the relationship between SCDI and HDI (Human Development Index). Based on the results of factor analysis, there are six factors formed where the highest SCDI with a population of fewer than 200,000 people in Madiun City (East Java Province), the highest SCDI with a population between 200,000 to 1,000,000 people in Yogyakarta City (DI Yogyakarta Province) and the highest SCDI with a total population of over than 1,000,000 people in Tangerang City (Banten Province). The results of uncertainty analysis and sensitivity analysis show that the formed SCDI is robust and reliable. In general, SCDI has a positive relationship to Human Development Index (HDI). The construction of this index aims to facilitate local and central governments in reviewing policies regarding the distribution of funds so that the smart city's development is by existing conditions.

1. Introduction

Bappenas (2016) states that Sustainable Development Goals (SDGs) focus on sustainable improvement in the economic welfare of the community, the sustainability of the social life of the community, the quality of the environment, ensures justice, and the implementation of governance that can maintain the improvement of the life quality. Indonesia is one of 193 countries that has been approving the SDGs Agenda in 2015. The SDGs consist of 17 goals and 169 targets related to sustainable development issues. In the SDGs, the 11th goal is to make cities and human settlements inclusive, safe, resilient, and sustainable. The idea of this city emerged as a response to the urbanization process that occurred in the world. In 2015, Bappenas approved Indonesia's seriousness in achieving these goals by issuing the Convergence of Development Agenda by The United Nations Development Programme (UNDP) like Nawa Cita (Nine-Point Development Agenda), RPJMN (Rencana Pembangunan Jangka Menengah Nasional or National Medium-Term Development Plan), and SDGs (UNDP, 2015).

To realize this goal, Indonesia has made a development implementation plan in the RPJMN 2015-2019. Policies that are in line with these objectives are (i) the realization of the National Urban

System; (ii) Accelerating the fulfillment of Urban Service Standards; (iii) Development of green and climate-resilient cities and disasters; (iv) Development of competitive smart city's based on technology and local culture; (v) Capacity building for urban development governance. UNDP (2015) states that Nawa Cita policy is in line with this goal is the 3rd goal, like developing Indonesia from the periphery with strengthening regions and villages within the framework of a unitary state. Furthermore, it is also in line with the 8th goal, like carrying out a national character revolution through a policy of restructuring the national education curriculum by prioritizing aspects of civic education, such as teaching the history of nation-building, values of patriotism, and love for the homeland, the spirit of defending the country and character in the education curriculum Indonesia.

The urban population in Indonesia is growing at an average of 4.1 percent per year faster than the urban population of other Asian countries (World Bank, 2016). The high population growth in urban areas raises many problems, not only demographic issues but also economic activity. One of them is the shift in the concentration of employment from the agricultural sector to the non-agricultural sector. The impact resulting from this shift in employment concentration will cause problems, especially in the increasing slum neighborhood, and unhealthy air quality, so it can interfere with the population health in an area. The high population growth did not follow GDP value, where Indonesia only got 4 percent lower than other Asian countries. These show that labor productivity is still relatively low, and income inequality is a serious problem and will affect the economy, especially in overcoming poverty, unemployment, and crime.

The World Bank (2016) also states that the development of urban areas did not follow good management, which management does not spend enough on infrastructure. Between the mid to late 2000s, Indonesia's economic growth expanded by an average of 5.8 percent, but infrastructure investment only increased 3 percent. Indonesia's economic growth has resulted in an infrastructure deficit, limiting the ability of cities to improve people's welfare. The quality of urban infrastructure in Indonesia is still poor, especially in access to base services like clean water, sanitation, electricity, and public transportation that is limited and uneven. Urban as the center of various economic activities, trade, and education will have the consequence that more migrants will be able to add the city problems so that it becomes more complex and causes the city's performance to decline. The complexity of issues in urban areas includes a decrease in the quality of public services, reduced availability of residential land, congestion on roads, excessive energy consumption, garbage accumulation, increased crime rates, and other social problems. Therefore, development in urban areas requires city management to solve existing problems.

Based on the Decree of the Minister of National Development Planning/Head of Bappenas Number Kep.14/M.PPN/HK/02/2015 concerning the Establishment of the National Urban Development Strategic Coordination Team, considering that 2015 is the initial stage in achieving city development, one of which is the development of smart cities are competitive, use technology, and local culture. Caragliu et al. (2011) state that the smart city is a city that can use human resources, social capital, and modern telecommunications infrastructure to realize sustainable economic growth and high quality of life, with wise resource management through community-based government participation. Currently, Indonesia has issued a development policy for smart cities in 2015-2019 in Indonesia, namely smart cities development as a whole (full scale) in 7 metropolitan urban areas as pilot projects. The strategies calculated by the government to realize the development of smart cities include: (i) Developing the economy through city branding that supports nation branding, (ii) Providing infrastructure and public services through the use of Information and Communication Technology (ICT), and (iii) Building community capacity that is innovative, creative, and productive (Bappenas, 2015). So, with this policy, a measure is needed to identify which areas are ready to support Smart Cities development.

Several researchers and organizations that use indicators for constructing the Smart cities development include Giffinger et al. in 2007, Cohen in 2012, UCLG in 2012, and Lombardi et al. in 2011 (Ahvenniemi et al., 2017). Giffinger et al. (2007) construct a European Smart Cities Index (ESCI) and use it to identify areas ready for smart cities development. ESCI describes the factors of Smart Cities development from the economy, people, governance, mobility, environment, and living. The Ministry of Communication and Informatics Indonesia in 2015 evaluation of the construction of the smart cities development in 93 selected cities in Indonesia with criteria, such as economic, social, and environmental aspects. Bappenas (2015) states that smart cities have a high population density with their main activities in the non-agricultural sector or have more urban areas than rural areas. On The Regulation of The Head of Statistics Indonesia (Perka BPS), No. 37 of 2010 concerning the classification of urban-rural in Indonesia states that 100 cities have more than 50 percent urban area. These cities will be the focus of researches on the construction of the Smart City Development Index.

Researches on Smart cities development are still not widely calculated in Indonesia, so it is necessary to do more in-depth. Therefore, the researcher wants to establish a measure that has expected to provide more detailed information on selected city's known as the Smart City Development Index (SCDI). The objectives of this study are to explain the general description of the characteristics of smart cities development, analyze the stages of the formation of the SCDI, examine the level of uncertainty analysis and sensitivity analysis of the SCDI, and link the between SCDI and other indicators.

2. Methodology

2.1. Study Area

The measurement of the smart city development, in this study at the city level. The research object in this study is cities in Indonesia that have more than 50 percent urban areas. Based on The Regulation of The Head of Statistics Indonesia, (Perka BPS) No. 37 of 2010 was obtained where 100 of 514 cities with more than 50 percent urban area in Table 1. Based on the classification of the island, there are 26 cities on the Sumatera Island, 50 cities on the Java-Bali Island; 3 cities on the Nusa Tenggara Island; 7 cities on the Kalimantan Island; 10 cities on the Sulawesi Island; 4 cities on the Maluku-Papua Island.

Table 1. The Object of Research.

No	Code	Province	Region	No	Code	Province	Region
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	1171	Aceh	Banda Aceh	19	1671	South Sumatera	Palembang
2	1173	Aceh	Langsa	20	1672	South Sumatera	Prabumulih
3	1174	Aceh	Lhokseumawe	21	1674	South Sumatera	Lubuk Linggau
4	1271	North Sumatera	Sibolga	22	1771	Bengkulu	Bengkulu
5	1272	North Sumatera	Tanjung Balai	23	1871	Lampung	Bandar Lampung
6	1273	North Sumatera	Pematang Siantar	24	1872	Lampung	Metro
7	1274	North Sumatera	Tebing Tinggi	25	2171	Kepulauan Riau	Batam
8	1275	North Sumatera	Medan	26	2172	Kepulauan Riau	Tanjung Pinang
9	1276	North Sumatera	Binjai	27	3101	DKI Jakarta	Kepulauan Seribu*
10	1371	West Sumatera	Padang	28	3171	DKI Jakarta	South Jakarta
11	1372	West Sumatera	Solok	29	3172	DKI Jakarta	East Jakarta
12	1373	West Sumatera	Sawah Lunto	30	3173	DKI Jakarta	Central Jakarta
13	1374	West Sumatera	Padang Panjang	31	3174	DKI Jakarta	West Jakarta
14	1375	West Sumatera	Bukit Tinggi	32	3175	DKI Jakarta	North Jakarta
15	1376	West Sumatera	Payakumbuh	33	3201	West Java	Bogor*
16	1377	West Sumatera	Pariaman	34	3204	West Java	Bandung*
17	1471	Riau	Pekan Baru	35	3209	West Java	Cirebon*
18	1571	Jambi	Jambi	36	3216	West Java	Bekasi*

Note: * classify regency

No	Code	Province	Region	No	Code	Province	Region
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
37	3271	West Java	Bogor	69	3603	Banten	Tangerang*
38	3272	West Java	Sukabumi	70	3671	Banten	Tangerang
39	3273	West Java	Bandung	71	3672	Banten	Cilegon
40	3274	West Java	Cirebon	72	3673	Banten	Serang
41	3275	West Java	Bekasi	73	3674	Banten	South Tangerang
42	3276	West Java	Depok	74	5103	Bali	Badung*
43	3277	West Java	Cimahi	75	5104	Bali	Gianyar*
44	3278	West Java	Tasikmalaya	76	5171	Bali	Denpasar
45	3279	West Java	Banjar	77	5271	West Nusa Tenggara	Mataram
46	3310	Central Java	Klaten*	78	5272	West Nusa Tenggara	Bima
47	3311	Central Java	Sukoharjo*	79	5371	East Nusa Tenggara	Kupang
48	3319	Central Java	Kudus*	80	6171	West Kalimantan	Pontianak
49	3320	Central Java	Jepara*	81	6371	South Kalimantan	Banjarmasin
50	3371	Central Java	Magelang	82	6372	South Kalimantan	Banjar Baru
51	3372	Central Java	Surakarta	83	6471	East Kalimantan	Balikpapan
52	3373	Central Java	Salatiga	84	6472	East Kalimantan	Samarinda
53	3374	Central Java	Semarang	85	6474	East Kalimantan	Bontang
54	3375	Central Java	Pekalongan	86	6571	North Kalimantan	Tarakan
55	3376	Central Java	Tegal	87	7171	North Sulawesi	Manado
56	3402	DI Yogyakarta	Bantul*	88	7172	North Sulawesi	Bitung
57	3404	DI Yogyakarta	Sleman*	89	7173	North Sulawesi	Tomohon
58	3471	DI Yogyakarta	Yogyakarta	90	7271	Central Sulawesi	Palu
59	3515	East Java	Sidoarjo*	91	7371	South Sulawesi	Makassar
60	3571	East Java	Kediri	92	7372	South Sulawesi	Pare Pare
61	3572	East Java	Blitar	93	7373	South Sulawesi	Palopo
62	3573	East Java	Malang	94	7471	Southeast Sulawesi	Kendari
63	3574	East Java	Probolinggo	95	7472	Southeast Sulawesi	Bau Bau
64	3575	East Java	Pasuruan	96	7571	Gorontalo	Gorontalo
65	3576	East Java	Mojokerto	97	8171	Maluku	Ambon
66	3577	East Java	Madiun	98	8271	North Maluku	Ternate
67	3578	East Java	Surabaya	99	9171	West Papua	Sorong
68	3579	East Java	Batu	100	9471	Papua	Jayapura

Note: * classify regency

2.2. Smart City Concept

Giffinger et al. (2007) state that a city's performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the Smart combination of endowments and activities of self-decisive, independent, and aware citizens. Smart city generally refers to the search and identification of intelligent solutions which allow modern cities to enhance the quality of the services provided to citizens.

Harrison et al. (2010) state that cities connect the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city.

Caragliu et al. (2011) state that a city is smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth, and high quality of life, with a wise management of natural resources, through participatory governance.

Bakici et al. (2012) state that a smart city is a high-tech intensive, advanced city that connects people, information, city elements using new technologies to create a sustainable, greener city, competitive, innovative commerce, and increased life quality.

Barrionuevo et al. (2012) state that a smart city means using all available technology, resources in an intelligent and coordinated manner to develop urban centers that integrate, habitable, and sustainable.

Kourtit et al. (2012) state that a smart city has high productivity, a relatively high share of highly educated people, knowledge-intensive jobs, output-oriented planning systems, creative activities, and sustainability-oriented initiatives.

Lombardi et al. (2012) state that information and communications technology (ICT) affects human capital/education, social and relational capital, and environmental issues by the notion of the smart city.

Marsal-Llacuna et al. (2014) state that smart cities have to improve urban performance. Data and information technologies (IT) usage is to provide more efficient services to citizens, monitor and optimize existing infrastructure, increase collaboration among different economic actors, and encourage innovative business models in both the private and public sectors.

2.3. Smart City Framework

To study the Smart city performance measurement systems, selected a set of Smart city assessment frameworks for the analysis. The frameworks use three criteria:
(1) The framework should clearly with measuring smartness,
(2) Enough detailed level information about indicators and methods had to be available, and
(3) The framework should cover several areas of city functions.
Smart cities frameworks are in Table 2.

Table 2. Smart City Framework.

Framework	Description	Source	Dimension	Indicators
(1)	**(2)**	**(3)**	**(4)**	**(5)**
European Smart Cities Ranking	European ranking elaborated and published by an international consortium headed by the Vienna University of Technology.	Giffinger et al. (2007)	6	64
The Smart Cities Wheel	An international holistic framework for considering all components of what makes and supports smart city benchmarking.	Cohen (2012)	6	26
Bilbao Smart Cities Study	The study was initiated at the Bilbao World Summit, giving an overview of the current situation of cities in different regions of the world.	UCLG (2012)	6	48
Triple-Helix Network Model for Smart Cities Performance	Model analyzing interrelations between the components of smart cities, including the humans, and social relations.	Lombardi et al. (2011)	5	45

2.4. Smart City Dimension

The Smart city development has as many as six dimensions like economic, people, governance, mobility, environmental, and living. This dimension consists of 56 indicators. The measurement scale is an interval. The data for indicator describes various conditions in line with the emphasis between the role of the government and community participation while maintaining the balance and sustainability of cities to realize smart city's development in the future. The variables used in this study are from data provided by Statistics Indonesia (BPS) in 2018, which comes from two sources like publications and raw data. The publication sources used BPS Publications (GRDP, HDI, and Poverty Statistics). The raw data comes from National Socio-Economic Survey and Village Potential Data Collection. Although the indicators selected in the present study cannot be considered a description of the different socio-economic contexts, they provide a broad qualification of the economic structure, social traits, and environmental characteristics observed in the Indonesian municipalities. Scheme the number of indicators selected by dimension is in Table 3.

Table 3. Scheme the Number of Indicators Selected by Dimension.

Dimension	**Concept Limitation**	**Indicators**
(1)	**(2)**	**(3)**
Economy	The Smart economy was the ability to overcome economic challenges, create new jobs, build new businesses, and increase regional attractiveness and competitiveness (Alawadhi et al., 2012).	6
People	The Smart people are more concentrated on knowledge workers more likely the city will innovate and pursue higher socio-economic development (Akcura et al., 2014).	6
Governance	Smart governance is making the right policy and implementing effectively and efficiently. Smart governance is a part or dimension of a Smart City that specializes in governance. Smart governance includes all the requirements, criteria, objectives for the empowerment and participation of the communities together. Important points related to the description of Smart governance include disclosure of public information. Government is a public service that is responsible to the community. Therefore, information related to development plans should be available through various information media (Batty et al., 2012).	3
Mobility	Smart mobility is a city with easy movement. These ensure the availability of innovative and sustainable means of public transport, promoting vehicles usage with low environmental impact (Alberti, 2011).	4
Environment	The Smart environment is an environment where you can acquire and apply knowledge about the community and its surroundings to adapt to the community to achieve the goals of convenience and efficiency (Marsa-Maestre et al., 2008).	12
Living	Smart living also means a measurable quality of life. These qualities are dynamic in the sense that they are always trying to improve themselves. Cultural achievements in humans are directly or indirectly the result of Smart living, including the proportion of the area for recreational sports and leisure use, number of public libraries, total book loans, and other media, museum visits, theater, and cinema attendance (Lombardi et al., 2012).	25

2.5. Smart City Indicator

The procedure to build up the composite index of smart cities development consists of nine steps, starting from the framework, variables selection, missing data imputation, normalization data, multivariate statistical analysis, weight derivation, indicators composition, and analysis of the obtained index. The formed factors can be quantified, thus allowing for an objective assessment of the territorial contexts favoring the smart cities. So simplicity in model building and flexibility in the use of relevant variables (OECD, 2008).

Table 4. Smart City Indicator.

Code	Indicator	Source	Sign*
(1)	(2)	(3)	(4)
SMART ECONOMY			
A1	Gross Regional Domestic Product	GRDP Publication	+
A2	Real per capita expenditure	HDI Publication	+
A3	Unemployment Rate	National Socio-Economic Survey	-
A4	Labor Force Participation Rate	National Socio-Economic Survey	+
A5	Full-time workers	National Socio-Economic Survey	+
A6	Workers in the formal sector	National Socio-Economic Survey	+
SMART PEOPLE			
B1	Population with a basic education certificate	National Socio-Economic Survey	-
B2	Population with a secondary education certificate	National Socio-Economic Survey	+
B3	Population with a higher education certificate	National Socio-Economic Survey	+
B4	Literacy Rate	National Socio-Economic Survey	+
B5	The average length of the school	HDI Publication	+
B6	Expected length of the school	HDI Publication	+
SMART GOVERNANCE			
C1	Cell phone usage	National Socio-Economic Survey	+
C2	Computer usage	National Socio-Economic Survey	+
C3	Internet access usage	National Socio-Economic Survey	+
SMART MOBILITY			
D1	Widest type of road surface quality asphalt	Village Potential Data Collection	+
D2	Road accessibility throughout the year	Village Potential Data Collection	+
D3	Presence of public transportation on fixed routes	Village Potential Data Collection	+
D4	Major public transport operations every day	Village Potential Data Collection	+
SMART ENVIRONMENT			
E1	Water pollution	Village Potential Data Collection	-
E2	Soil pollution	Village Potential Data Collection	-
E3	Air pollution	Village Potential Data Collection	-
E4	Environmental conservation activities	Village Potential Data Collection	+
E5	Waste processing/recycling activities	Village Potential Data Collection	+
E6	Work together for the general activities	Village Potential Data Collection	+
E7	Work together for the specific activities	Village Potential Data Collection	+
E8	Natural disasters	Village Potential Data Collection	-
E9	Managed nature reserves	Village Potential Data Collection	+
E10	Fights/level of security maintained	Village Potential Data Collection	-
E11	Sewage that is polluting the river water	Village Potential Data Collection	-
E12	Existent slums	Village Potential Data Collection	-
SMART LIVING			
F1	Life Expectancy	HDI Publication	+
F2	Population with the poor condition	Poverty Statistics Publication	-
F3	Poverty Line	Poverty Statistics Publication	-
F4	Health complaints	National Socio-Economic Survey	-
F5	The largest building material for the roof of the house	National Socio-Economic Survey	+
F6	Main building materials of the widest house walls	National Socio-Economic Survey	+
F7	Defecation facilities	National Socio-Economic Survey	+
F8	Septic tank waste final disposal	National Socio-Economic Survey	+
F9	Accessing sources of clean drinking water	National Socio-Economic Survey	+
F10	Accessing clean water sources	National Socio-Economic Survey	+
F11	PLN's electric lighting sources	National Socio-Economic Survey	+

Code (1)	Indicator (2)	Source (3)	Sign* (4)
F12	Electric cooking fuel percentage	National Socio-Economic Survey	+
F13	Victims of crime/crime rate	National Socio-Economic Survey	-
F14	Access to the elementary school	Village Potential Data Collection	+
F15	Access to the junior high school	Village Potential Data Collection	+
F16	Access to the senior high school	Village Potential Data Collection	+
F17	Access to the university	Village Potential Data Collection	+
F18	Access to the hospital	Village Potential Data Collection	+
F19	Access to the maternity hospital	Village Potential Data Collection	+
F20	Access to the public health center	Village Potential Data Collection	+
F21	Access to the polyclinic	Village Potential Data Collection	+
F22	Access to the doctor's office	Village Potential Data Collection	+
F23	Access to the midwife practice	Village Potential Data Collection	+
F24	Access to the village health post	Village Potential Data Collection	+
F25	Access to the medicine	Village Potential Data Collection	+

Note: * sign + shows unidirectional and sign - shows opposite directional

2.6. Data Analysis

Goal 1. Reviewing indicators related to smart city's development. This objective is answered with a literature review and descriptive analysis to find out the general description of the characteristics of smart cities development. Visualization of descriptive analysis uses histograms, pie charts, bar charts, or others. In determining the selecting variables for descriptive analysis, an exploratory factor analysis method uses the R application with the information about the mean, standard deviation, minimum and maximum values.

Goal 2. Construction of SCDI. This objective uses the index construction method guided by the composite index construction stage by the OECD.

Goal 3. Measuring the uncertainty and sensitivity of composite indicators to increase transparency in policy-making from the resulting composite indicators. This objective uses the methods of uncertainty analysis and sensitivity analysis. This method has tried various combinations of weighting methods on the index used by Statistics Indonesia (BPS) and OECD.

Goal 4. Linking SCDI with other indicators. This objective uses the scatter plot method or correlation analysis between SCDI and Human Development Index (HDI).

2.7. Factor Analysis

Factor analysis is a technique to examine the patterns or relationships underlying several variables and to determine whether the summarized information is a new set of variables, referred to as factors. Hair et al. (2010) state that formed indicators can represent the variables contained. Factor analysis seeks to simplify complex and diverse relationships within a set of variables by uncovering dimensions or factors that link together seemingly unrelated variables, thereby providing insight into the underlying data structure (Dillon et al., 1984). Hair et al. (2010) state that the stages of factor analysis are as follows:

a. Determine what variables will be analyzed.
b. Test the variables that are feasible to enter the factor analysis stage.
  - ✓ Bartlett's Test of Sphericity
    Bartlett's Test of Sphericity is a statistical test used to see the significance of the correlation between variables as a whole from a correlation matrix. The data deserves to be analyzed by factor analysis if there is a correlation between the variables used or the correlation matrix is not an identity matrix.
  - ✓ Kaiser-Meyer-Olkin (KMO)
    The KMO method measures the adequacy of the overall sample and is used to compare the observed correlation coefficient with the partial coefficient (OECD, 2008). The KMO value should be above 0.6 so that it can be analyzed using factor analysis.

- ✓ The Measure of Sampling Adequacy (MSA)
  Hair et al. (2010) stated that a variable is feasible to do factor analysis if the MSA value is more than 0.5.

c. Determine the method of factor analysis (extraction)
   Factor extraction is the process of reducing the number of variables into several new sets of variables. This study uses a method of determining the number of factors, namely by looking at the eigenvalues or the percentage value of variance (determination of the number of factors analysis).

d. Interpreting factors
   Factor interpretation by classifying the variables that have the highest loading factor to be classified as related factors.

2.8. Composite Index

Based on the Organization for Economic Co-operation and Development (2008) in the publication of the Handbook on Constructing Composite Indicators, the steps in constructing a composite index are as follows.

1) Development of the theoretical framework
   The theoretical framework is to select and combine variables to become a meaningful composite indicator. The theoretical framework provides a clear framework and definition of the phenomenon to be measured.
2) Indicator selection
   The selection of indicators is to check the quality of the available variables through consideration of their advantages and disadvantages in terms of availability, timeliness, data sources, and relevance.
3) Missing data imputation
   Data imputation is to produce a complete data set and estimate the missing value, provide a measure of the reliability of the imputed value so that it can be seen its effect on the results of composite indicators, and detect outliers.
4) Data normalization
   Data often has different units of measurement, so it is necessary to normalize the data so that the variables used in the analysis process are comparable. The method used for normalization is a min-max method. The sign '+' shows unidirectional and sign '-' shows opposite directional with the formula:
   The sign '+' shows:

$$I_{ij} = \frac{X_{ij} - min_i}{max_i - min_i} \quad (1)$$

   The sign '-' shows:

$$I_{ij} = 1 - \frac{X_{iI} - min_{iI}}{max_i - min_i} \quad (2)$$

5) Multivariate analysis
   Multivariate analysis is examining to the structure of the data set. There are several techniques of multivariate analysis. The multivariate analysis used in this study was exploratory factor analysis.
6) Determine the weight
   Unequal weight is a weight for each indicator formed from the results of factor analysis. The weights are obtained by dividing the loading factor of each indicator divided by the average loading factor in each dimension and then multiplied by the variance value in each dimension. Furthermore, the weights are normalized by dividing the weights on the indicator divided by the total weights of all dimensions. The weighting of each indicator is calculated based on the value of the loading factors it has and the value of the rotation sums of squared loading (percent of

variance) through the following two stages:
Stage 1: Calculation of the weight of each indicator in one dimension

$$\text{Weight}_i = \frac{\text{factor loading}_i}{\text{average factor loading}_i} \text{ x RSSL}_k \tag{3}$$

Stage 2: Calculation of the standard weight of each indicator in one dimension

$$\text{Standard Weight}_i = \frac{\text{weight}_i}{\sum_{i=1}^{m} \text{weight}_i} \tag{4}$$

Factor loading $_i$	= factor loading indicator i
RSSL $_k$	= rotated sum squares loading factor k
Weight $_i$	= weighing indicator i
Standard Weight $_i$	= standardized weighing indicator i
m	= number of weights

7) Estimated factor score

The factor score is a composite measure of each original variable for each factor extracted in factor analysis (Hair et al., 2010). The factor score is also a composite score estimated for each respondent on the derivative factors. The explanation of factor estimation is in results.

8) Aggregation

Aggregation is the process of the final value of various indicators as a composite index. This study performs aggregation by adding up the multiplication between the weights of each factor and the factor scores of each city. Firstly, the index value for each dimension uses the following formula:

Stage 1: Calculation of dimension value

$$\text{Dimension}_k = \sum_{i=1}^{r} \text{standard weight}_i \text{ x indicator value}_{ij} \tag{5}$$

Stage 2: Calculation of SCDI value

$$\text{SCDI}_j = \sum_{k=1}^{s} \text{Dimension}_k \tag{6}$$

Stage 3: Calculation of Indonesia's SCDI value

$$\text{SCDI}_{\text{INDONESIA}} = \frac{\sum_{j=1}^{n} \text{SCDI}_j}{n} \tag{7}$$

SCDI_j	= Smart City Development Index (city j)
r	= number of subdimensions
s	= many dimensions
n	= the number of cities

3. Results

3.1. Principal Component Analysis

The results of the principal component analysis calculated on the matrix composed of 56 variables observed at the level of 100 cities are reducted as 21 variables based on Bartlett's Test of Sphericity, Kaiser-Meyer-Olkin (KMO), and Measure of Sampling Adequacy (MSA). Based on the results of the processing, the KMO value of 0.795 was obtained which illustrates that the data is good enough for factor analysis. The results of Bartlett's Test of Sphericity show a p-value of 0.00 which is smaller than the alpha significance of 5 percent (0.05) which indicates that the correlation matrix is not an identity matrix, or there is a significant correlation between the variables used, so that factor analysis can be calculated. The MSA value for each variable is above 0.5 which means the data used is good enough for factor analysis (Sharma, 1996). PCA extracted with absolute eigenvalue is more than 1. The extracted proportion of variance 73.39 percent is high considering the huge number of input variables. The number of dimensions is as many as 6 dimensions.

Table 5. Dimension of SCDI.

No	Dimension	Variance	Eigen Value
(1)	(2)	(3)	(4)
1	Education and Health Access	22.19	8.73
2	People and Governance	17.29	6.00
No	**Dimension**	**Variance**	**Eigen Value**
(1)	**(2)**	**(3)**	**(4)**
3	Income and Environmental Eligibility	9.72	4.85
4	Joint Action, Housing, and Health	8.87	2.81
5	Manpower Readiness	8.48	1.75
6	Pollution	6.84	1.55
	Total	**73.39**	

3.2. Weighting Indicator

The weights are obtained by dividing the loading factor of each indicator divided by the average loading factor and then multiplied by the variance in each dimension. Furthermore, the weights are normalized by dividing the weights on the indicator divided by the total weight of all dimensions.

Table 6. Weighting Indicator.

No	Dimension	Indicator	Weight
(1)	(2)	(3)	(4)
1	Education and Health Access	**Education Access**	
		X26 - Access to the junior high school	0.0420
		X27 - Access to the senior high school	0.0481
		X28 - Access to the university	0.0477
		Health Access	
		X29 - Access to the hospital	0.0480
		X30 - Access to the maternity hospital	0.0333
		X31 - Access to the public health center	0.0463
		X32 - Access to the polyclinic	0.0460
		X33 - Access to the doctor's office	0.0364
		X34 - Access to the midwife practice	0.0441
		X35 - Access to the medicine	0.0434
2	People and Governance	**People**	
		X6 - Population with a basic education certificate	0.0373
		X7 - Population with a secondary education certificate	0.0220
		X8 - Population with a higher education certificate	0.0389
		X10 - The average length of the school	0.0381
		X11 - Expected length of the school	0.0338
		Governance	
		X12 - Cell phone usage	0.0347
		X13 - Computer usage	0.0376
		X14 - Internet access usage	0.0290
3	Income and Environmental Eligibility	**Income**	0.0420
		X1 - GRDP	0.0481
		X2 - Real per capita expenditure	0.0477

No	Dimension	Indicator	Weight
(1)	(2)	(3)	(4)
		Environmental Eligibility	
		X15 - Presence of public transportation on fixed routes	0.0135
		X21 - Existent slums	0.0162
		X25 - Accessing clean water sources	0.0213
4	Joint Action, Housing, and Health	**Joint Action**	
		X17 - Waste processing/recycling activities	0.0166
		X18 - Work together for the general activities	0.0224
		X19 - Work together for the specific activities	0.0200
		Housing and Health	
		X22 - Life expectancy	0.0136
		X23 - Material for the roof of the house	0.0177
		X24 - Material of the widest house walls	0.0141
5	Manpower Readiness	**Manpower Readiness**	
		X3 - Labor Force Participation Rate	0.0191
		X4 - Full-time worker	0.0207
		X5 - Formal sector workers	0.0158
		X9 - Literacy Rate	0.0109
6	Pollution	**Water Pollution**	
		X16 - Water pollution	0.0133
		X20 - Sewage that is polluting the river water	0.0135
Total			**1**

4. Discussion

4.1. Description of the Characteristic of Smart City Development in Indonesia

In general, Indonesian people tend to have a GRDP of Rp 53,356.21 billion by X1. However, there are still many regions whose GRDP is still far from the average value. In addition, the variable X2 shows the real per capita expenditure of the Indonesian people at about Rp 13,572.14. Next, Labor Force Participation Rate, in general, the community has participated in the working-age (productive) by X3. The variable X4 shows the percentage of full-time workers is only 51.52 percent, and the variable X5 shows the percentage of workers in Indonesia is still below 50 percent. Next, the certificate that was last completed by X6, X7, and X8, it is seen that the proportion is more indicated by secondary education certificate with 42.51 percent by X7. Meanwhile, from the Literacy Rate variable by X9, where only 1.58 percent are still illiterate. In contrast, variable X11 is the expected length of schooling to be achieved is 14.15 years. The variable X10, like the average length of the school, is only 10.42 years, which means it is still far below expectations. The variables X12, X13, and X14 indicate the use of cellphones, computers, and access to the internet that many people use cellphones but rarely use computers. On the other hand, the number of people who access the internet has almost reached 50 percent, which means that half of the people in cities have to access the internet. Furthermore, the existence of public transportation with fixed routes as indicated by X15 is 70.59 percent.

The condition of the community is good enough because more than 50 percent are not experiencing water pollution by X16. Meanwhile, the variable X17 shows the percentage of villages involved in waste recycling processing activities is only 32.89 percent. The variables X18 and X19, which indicate the percentage of villages joining in cooperation activities, are more dominated by special interests than public interests. While the variable X20 states percentage of villages with river water not polluted by waste is 57.63 percent. Variable X22 shows Life Expectancy is 72.26 years. These indicate that the health condition of the Indonesian people is quite good. However, when viewed from the housing conditions, the variables X23, X24, and X25 which show the percentage of villages with the (largest) roofs in the form of tiles, (widest) walls in the form of walls, and the (main) source of clean drinking water used successively 45.27 percent, 86.40 percent, and 14.82 percent. Meanwhile, for the variable of education access indicated by X26, X27, and X28, the ease of access to education in junior high schools is 43.69 percent compared to others by X26. For the variable of health access indicated by X29 to X35, it can be seen that X29 has the largest ease of access to health care at the hospital with 43.66 percent.

4.2. Stages of Construction SCDI in Indonesia

The number of dimensions as many as six dimensions with the amount of each variation that can be explained by dimension 1 (22.19 percent), dimension 2 (17.29 percent), dimension 3 (9.72 percent), dimension 4 (8.87 percent), dimension 5 (8.48 percent), and dimension 6 (6.84 percent). These indicate that dimension 1 has a high contribution in explaining the formed factors. Based on the existing cumulative variance, factoring with six dimensions is considered sufficient.

To see further the dimensions that construct the SCDI the most contributing to the index, the dimension with the lowest contribution value is dimension 6 (pollution) of 1.63 because this dimension only consists of two indicators. The facts show that pollution in Indonesia is still 34.76 percent of villages experiencing water pollution and 42.37 percent of villages experiencing waste pollution in river water. In addition, this dimension is still relatively low in smart city development readiness because the contribution in this index only reaches 6.84 percent. Meanwhile, the highest contribution value is dimension 1 (education and health access) of 17.39. These show that high access in education access reaches 42.16 percent and health access reaches 38.49 percent. In addition, this dimension is already good enough in readiness for Smart cities development because the contribution in this index has reached 22.19 percent.

Share given by each dimension is in line with the index value generated by each dimension in the SCDI. The largest share of smart cities development comes from the education and health access dimension, which is 37.70 percent, and the smallest share in Smart cities development comes from the pollution dimension, which is 3.54 percent. The high share of the education and health access dimension shows that this dimension contributes to the high readiness of smart cities development in Indonesian cities. The share dimensions of the SCDI are in Figure 1.

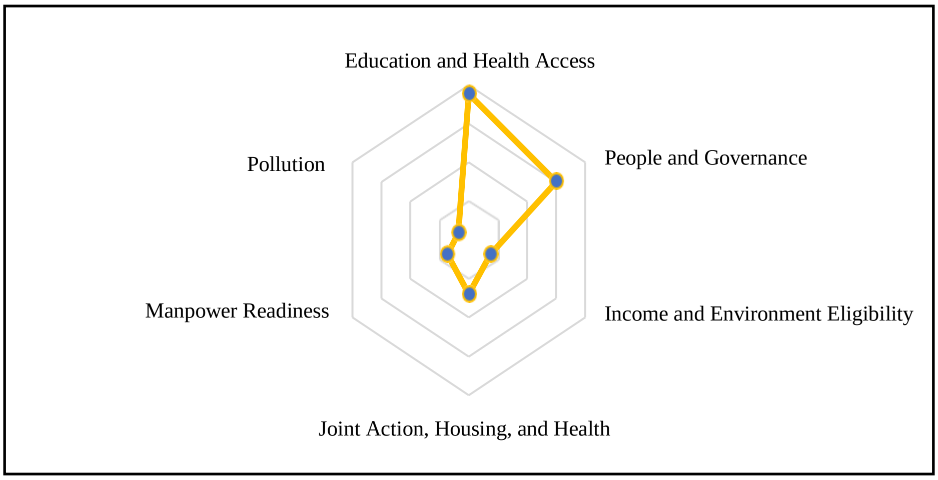

Figure 1. Share Dimensions of SCDI.

SCDI as an outcome-oriented performance index or development results. The SCDI measures regional conditions from various development dimensions based on predetermined achievement targets. The results of the preparation of the SCDI can help policy-makers, especially in providing a quantitative basis for comparing, analyzing, and understanding regional development performance.

From Table 7 and Table 8, there are 51 cities with SCDI values are above the Indonesian. The results of the Indonesian SCDI value showed an index is 46.14. The city with the highest SCDI in Madiun City (East Java Province) with 73.96, and the city with the lowest SCDI in Kepulauan Seribu Regency (DKI Jakarta Province) with 23.57.

Table 7. Cities with the Highest SCDI.

No	Region	Province	SCDI	No	Region	Province	SCDI
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Highest Smart City Development Index (SCDI)							
1	Madiun	East Java	73.96	6	Pare Pare	South Sulawesi	66.28
2	Blitar	East Java	73.65	7	Pontianak	West Kalimantan	64.51
3	Yogyakarta	DI Yogyakarta	71.42	8	Palu	Central Sulawesi	64.49
4	Denpasar	Bali	70.09	9	Salatiga	Central Java	64.05
5	Malang	East Java	66.45	10	Magelang	Central Java	63.33

Note: * classify regency

Table 8. Cities with the Lowest SCDI.

No	Region	Province	SCDI	No	Region	Province	SCDI
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Lowest Smart City Development Index (SCDI)							
1	Kepulauan Seribu*	DKI Jakarta	23.57	6	Tangerang*	Banten	27.49
2	Cirebon*	West Java	24.69	7	Lhokseumawe	Aceh	28.11
3	Bandung*	West Java	25.18	8	Tasikmalaya	West Java	28.31
4	Bogor*	West Java	25.59	9	Bitung	North Sulawesi	29.50
5	Prabumulih	South Sumatera	25.98	10	Bau Bau	Southeast Sulawesi	29.50

Note: * classify regency

Table 9. SCDI Classification by Population.

No	Region	Province	SCDI
(1)	(2)	(3)	(4)
Population < 200,000 people			
1	Madiun	East Java	73.96
2	Blitar	East Java	73.65
3	Pare Pare	South Sulawesi	66.28
4	Salatiga	Central Java	64.05
5	Magelang	Central Java	63.33
Population 200,000 – 1,000,000 people			
1	Yogyakarta	DI Yogyakarta	71.42
2	Denpasar	Bali	70.09
3	Malang	East Java	66.45
4	Pontianak	West Kalimantan	64.51
5	Palu	Central Sulawesi	64.49
Population > 1,000,000 people			
1	Tangerang	Banten	60.61
2	Makassar	South Sulawesi	59.76
3	North Jakarta	DKI Jakarta	57.61
4	Surabaya	East Java	55.34
5	South Jakarta	DKI Jakarta	52.86

Note: * classify regency

From Table 9, SCDI classification by population, the classification with a population of fewer than 200,000 people, the highest SCDI in Madiun City (East Java Province) with 73.96; classification with a population of 200,000 - 1,000,000 people, the highest SCDI in Yogyakarta City (DI Yogyakarta Province) with 71.42; and the classification with a population of over than 1,000,000 people, the highest SCDI is Tangerang City (Banten Province) with 60.61.

4.3. Uncertainty Analysis and Sensitivity Analysis from SCDI

Each city is ranked based on the SCDI value. Ranking for city uses in all scenarios. All scenarios use unequal weighing techniques: Scenario I - (Baseline Model), scenario II - Environment Indifferent Behaviour Index (Indeks Perilaku Ketidakpedulian Lingkungan Hidup - IPKLH), scenario III - Regional Development Index (Indeks Pembangunan Regional - IPR), scenario IV - Social Capital Index (Indeks Modal Sosial - IMS), and scenario V - Organisation for Economic Co-operation and Development (OECD). Therefore, it takes an average ranking change as minimal as possible or close to 0 (Salvati et al., 2014). The scenarios model is in Table 10.

Table 10. Characteristics of 5 Scenarios Model.

Scenario	Model	Weighting	Total	Aggregation
(1)	(2)	(3)	(4)	(5)
I	Baseline Model	Indicator	All	Linear
II	Environment Indifferent Behaviour Index	Indicator	Dimension	Arithmetic Mean
III	Regional Development Index	Indicator	Subdimension	Arithmetic Mean
IV	Social Capital Index*	Indicator	All	Linear
V	OECD	Dimension	All	Linear

Note: * using total factor loading for weighting

Results of the scenario in Table 11 that the average change in the ranking of cities (Rs) is from (1.12 to 2.60), and a value close to 0 indicates a good combination between the SCDI scenario I and other scenarios. Scenario IV has the high average change in city ranking (Rs), while scenario III has the low average changes in city ranking (Rs). In general, the resulting SCDI value has a low change in input factor changes, so it has a high certainty on the resulting index. Therefore, if an index undergoes drastic changes, it will illustrate that the index compiled does not have good certainty.

Table 11. Average Change in Ranking of 5 Scenarios.

	I	II	III	IV	V	Average	Rs
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
I	0	14.74	14.74	5.54	6.82	8.37	-
II	14.74	0	1.86	9.56	9.70	7.17	1.20
III	14.74	1.86	0	9.68	9.96	7.25	1.12
IV	5.54	9.56	9.68	0	4.06	5.77	2.60
V	6.82	9.70	9.96	4.06	0	6.11	2.26

While in Figure 2, it can be seen that most of the median rank of SCDI has a precision level below 40 percent which indicates the level of precision is categorized at high and medium levels. The level of precision in Figure 2 shows that the median rank will provide an alternative measure of the ranking of smart city development. That will show the range of potential rankings whether this index can measure certainty rankings in it.

ESRI (2011) stated that the coefficient of variation (CV) helps categorize the level of precision in this ranking case. In Figure 2, CV below 12% (45 cities) are in high precision, CV 12-40% (39 cities) are in moderate precision, CV above 40% (16 cities) indicate low precision in smart city rankings. This has shown that this index has high certainty (low uncertainty) and shows reliability.

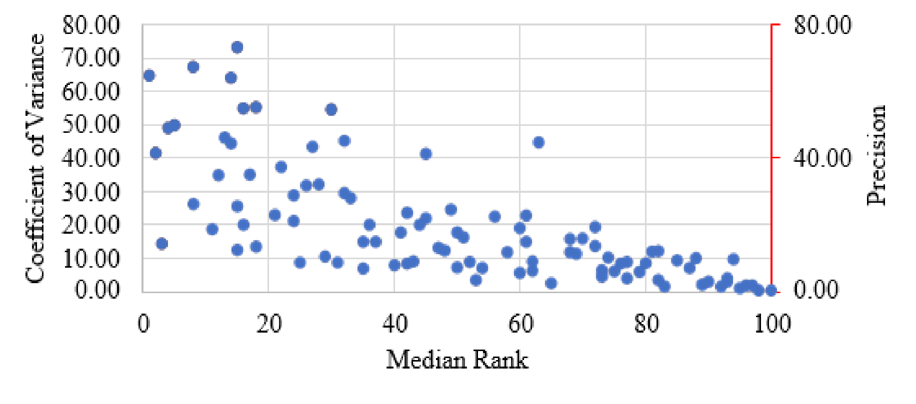

Figure 2. Comparison of CV and Precision Level with Median Rank SCDI.

The relationship between the median rank and CV by the Pearson correlation coefficient is -0.718. This shows a negative relationship between the median rank of the smart city and CV. In other words, the higher the CV in the city, the more heterogeneous the median rank variation, so it will show low precision as well, and vice versa. This indicates an alternative possibility of using the index as an approach to identify areas with the development is considered sufficient to describe the state of smart cities.

Table 12. Spearman Correlation between Baseline Rank and Scenario Rank.

	I	**II**	**III**	**IV**	**V**	**Median**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
I	1	0.796	0.794	0.969	0.953	0.950
II	0.796	1	0.996	0.913	0.902	0.930
III	0.794	0.996	1	0.911	0.900	0.928
IV	0.969	0.913	0.911	1	0.984	0.993
V	0.953	0.902	0.900	0.984	1	0.992
Median	0.950	0.930	0.928	0.993	0.992	1

Meanwhile, in testing sensitivity analysis, one can see the relationship between the baseline rank and the median rank as indicated by the magnitude of the Spearman correlation coefficient, which is 0.950. These indicate a positive relationship between the baseline and median ratings. Hamby (1994) states that the results of a significant correlation also show that the index already has low sensitivity to changes in ranking and has good sensitivity. In general, the SCDI value has met the criteria of low uncertainty and low sensitivity to the resulting scenarios that the formed SCDI is robust and reliable (Saisana et al., 2010).

4.4. Linking between SCDI and HDI

In general, there is a positive relationship between SCDI and the Human Development Index (HDI), where cities with low SCDI scores tend to have low HDI scores, and towns with SCDI scores tend to have high HDI scores. From the results of the quadrant analysis below, 35 cities do not follow the distribution pattern like other cities, where 18 cities have low SCDI scores and high HDI values (quadrant II). On the contrary, 17 cities have high HDI values (quadrant II). Low SCDI and HDI values (quadrant IV). Quadrants II and IV indicate that a high SCDI value does not necessarily mean a high HDI value and vice versa. In contrast to the other 65 cities that follow the distribution pattern of correlation values, 34 cities have high SCDI values and high HDI values (quadrant I), while 31 other cities have low SCDI values and low HDI values. Quadrants I and III show that a high SCDI value means a high HDI value, and vice versa.

The results based on the test show that the Pearson correlation coefficient between SCDI and HDI is 0.555 which indicates that there is a positive and quite strong relationship between SCDI and HDI (Alsaqr, 2021). If the HDI of a region increases, then the SCDI in a region will increase, and vice versa. The correlation analysis can prove that the formed SCDI has fairly high validity and is sensitive to phenomena related to development achievements.

5. Conclusion

Development in urban areas requires city management to solve problems that occur of high population growth. The complexity of the issues in urban areas varies widely, including a decrease in the quality of public services, reduced availability of residential land, congestion on the highway, excessive energy consumption, waste accumulation, increased crime rates, and other social problems. The result of factor analysis shows that six dimensions form the SCDI, start from dimension 1 (education and health access), dimension 2 (people and governance), dimension 3 (income and environmental eligibility), dimension 4 (the joint action, housing, and health), dimension 5 (manpower readiness), and dimension 6 (pollution). The results show that the SCDI value, where the highest SCDI area with a population of fewer than 200,000 people in Madiun City (East Java Province), the highest SCDI area with a population between 200,000 to 1,000,000 people in Yogyakarta City (DI Yogyakarta Province), and the highest SCDI area with a population above 1,000,000 people in Tangerang City (Banten Province). The SCDI value has criteria for low uncertainty and low sensitivity to several scenarios, and the SCDI is robust and reliable. The relationship between SCDI and HDI has a positive relationship where 65 cities follow this distribution pattern of correlation values. In addition, the suggestion from this study is to expand the measurement of the Smart city development index to all regions in Indonesia, add other indicators with consideration and adjustment from the expert and stakeholders. Review the improvement of the methodology, especially with the availability of indicators in areas so that comparability, and can assist local governments and the central government in reviewing policies regarding the allocation of funds so that the development of a Smart city is by existing conditions.

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