ESIC2024 Posted: 16/04/2024 DOI: 10.70082/esic/8.1.076

Development of an "Integrated Sustainability Performance Indicators" Model for the Smart City Program in Makassar

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Abstract

The Need to Understand Factors Influencing Community Participation in Smart City Programs and to Evaluate Their Impact on Urban Progress This study aims to explore the implementation of the Smart City concept in Makassar, focusing on aspects of inclusion, sustainability, and the application of telemedicine technology. The research employs a quantitative methodology, designing a structured questionnaire encompassing variables such as environmental quality, economic vitality, social equity, and technological innovation. Data were collected through various online platforms and analyzed using statistical techniques like correlation analysis and regression modeling. The findings indicate that the majority of participants are males under 30 years old, with backgrounds in farming and entrepreneurship, reflecting high interest in the Smart City concept among this demographic group. These insights are crucial for realizing an inclusive and sustainable Smart City in Makassar and highlight the importance of accessibility and active participation from all community sectors for the success of the Smart City program.

Keywords: Conceptual Model, Economy and Environment, Pandemic Resiliency, Smart City, Telemedicine.

The urban area has been the center of human civilization since ancient Greece to the modern era. In fact, urban areas occupy less than 5% of the Earth's surface but consume nearly 75% of natural resources in daily activities and emit 60-80% of greenhouse gases (Musango et al., 2017) This situation necessitates a reevaluation of existing policies and plans, given the significant increase in the world's population, to enhance the resilience and sustainability of cities for future generations.

Cities have become centers of technological innovation, economic growth, and modernization. In the 21st century, the digital revolution and technological advancements continuously influence all aspects of life, including social, economic, and environmental domains (Chourabi et al., 2012; Dobbins, 2011). However, critical challenges often arise amid these waves of change and reform, resulting in slow development in some cities concerning infrastructure, city organization, and public service processes.

Research explores the challenges and implementation of renewable energy infrastructure in cities by Caponio, Massaro, Mossa & Mummolo (2015). Their study concludes that governance appears inefficient, city capacities inadequate, and societal complexity leads to procedural deficits such as the absence of institutions to regulate framework creation or strategies (Fernandez-Anez et al., 2020; Lazaroiu & Roscia, 2012; Silva et al., 2018; Yin et al., 2015).These gaps introduce the concept of Smart Cities, focusing on urban revitalization processes aimed at reducing financial losses and environmental savings through technological engineering.

As cities worldwide strive towards becoming smart and more sustainable, it is crucial to develop effective methods to measure and track progress towards these goals (Anthopoulos, 2015). One attractive approach is the use of Integrated Sustainability Performance Indicators (ISPI), which provide a comprehensive and standardized way to evaluate the sustainability of smart city programs.

Smart City programs have the potential to revolutionize urban life by leveraging cutting-edge technology to enhance efficiency, connectivity, and sustainability (Caragliu et al., 2011; Giffinger et al., 2007a). However, to truly achieve these goals, Smart City must also prioritize inclusivity and accessibility for all citizens, including marginalized and underserved communities.

A city with a Smart City designation is one that initially has a new breakthrough in solving problems in its city and successfully improves its city's performance (Al Nuaimi et al., 2015; Batty et al., 2012; Insani, 2017). The goal of Smart City implementation is to shape and implement a safe, comfortable, controlled and accessible city for its citizens and strengthen the competitiveness of the city in terms of economic, social and technological Calvillo, Sanchez-Miralles´ & Villar (2017), provide more short definitions for Smart City and state that "Smart City is an efficient and sustainable city center that provides high quality of life for its inhabitants through optimal resource management (Letaifa, 2015; Meikle, 2014))." In other research classified specific activities related to energy as energy intervention including energy generation, energy storage, infrastructure, facilities, and transportation.

Based on the Kemkominfo website, the concept of Smart City adopted in Indonesia is initiated as cities that provide the fastest and most accurate solutions to their citizens. Suhono asserts that this Smart City concept comprises supportive components: smart economy, smart people, smart governance, smart government, smart mobility, smart environment, and smart living (Harrison & Donnelly, 2011).

Additionally, Boyd Cohen, a professional who has also examined the Smart City concept, annually publishes rankings for Smart City(Ahvenniemi et al., 2017) To create these rankings, he developed a measurement tool known as the Smart City Wheel, inspired by previous studies from The Center of Regional Science at the Vienna University of Technology, Siemens' Green City Index, and Buenos Aires' "Modelo Territorial" (Kumar & Dahiya, 2017; PUPR, 2015).The Smart City Wheel is based on six primary categories: smart economy, smart environmental practices, smart governance, smart living, smart mobility, and smart people (Silva et al., 2018).

Meanwhile, according to research by Azzam Abu-Rayash, the Smart City Index (SCI) is a composite indicator that combines various domains and indicators. The main domains utilized in this research are: Smart Environment, Smart Economy, Smart Society, Smart Governance, Smart Energy, Smart Infrastructure, Smart Transportation, and Pandemic Resiliency (Abu-Rayash & Dincer, 2021).

Makassar City was chosen to host the launch ceremony of the "Towards 100 Smart Cities" program (Nasrullah, 2017). Selecting Makassar City for this program launch was apt, considering the capital city of South Sulawesi province has been implementing concepts to address Smart Cities, namely the Sombere City and Smart City concepts (Amri, 2016; Manguluang, 2016). In Makassar, "Sombere" in the Makassarese language signifies hospitality, humility, and brotherhood. This concept has evolved into a cultural framework for utilizing digital technology (Smart) in Makassar City (Harlina & Mustafa, 2018). The Smart City program in Makassar is still in its developmental and renewal phase, thus facing various classic issues in its field implementation, particularly concerning the 5 Smart City Index (SCI) indicators.

Telemedicine refers to the practice of providing remote medical services through information and communication technologies, such as video conferencing, telephone, or mobile applications (Baker & Stanley, 2018; Chau & Hu, 2002). A Smart city integrates information and communication technologies to enhance residents' quality of life and city efficiency.

In the context of a Smart City, telemedicine can serve as a solution to improve healthcare service quality and resource efficiency in cities (Ayatollahi et al., 2015; Bahl et al., 2020). With telemedicine, patients can consult with doctors or medical professionals without visiting hospitals or clinics, thereby reducing traffic congestion and waiting times at healthcare facilities.

Regarding the implementation of the Smart City concept, the Makassar City Government applies 5 main concepts in Smart City development: smart economy, smart environment, smart mobility, smart governance, and smart people (Fathun, 2016). This study also utilizes 5 indicators, combining insights from three previous studies: smart economy, smart environment, smart governance, pandemic resiliency, and smart living, to develop the Integrated Sustainability Performance Indicators model for the Smart City Program in Makassar City (Nurdiassa et al., 2021).

This study focuses on the implementation of Integrated Sustainability Performance Indicators (ISPI) within the Smart City program of Makassar City. Through quantitative data analysis, this research evaluates the effectiveness of ISPI in monitoring progress towards sustainability goals, including improvements in energy efficiency, waste management, and transportation.

Methods

The research method utilizes regression analysis for multiple objectives: modeling and relationships (Chatterjee and Simonoff, 2013) between Smart City variables and Integrated Sustainability Performance indicators, as well as PLS-SEM (Partial Least Squares Structural Equation Modeling) to construct a PLS-SEM model with both structural and measurement models explaining the influence of Smart City variables. This method was chosen because it can handle small sample sizes and is more practical (Hair Jr et al., 2017) while also involving relationships between variables and Integrated Sustainability Performance through inclusive and equity indicators, as well as telemedicine indicators as mediating variables. Implementation of PLS-SEM will involve stages of structural and measurement model development (Leguina, 2015)

Smart City is not limited solely to the integration of Information and Communication Technology (ICT) (Bischof et al., 2014; Shruti et al., 2020). Instead, it is driven by data across all indicators, including environmental, economic, governance, quality of life, and pandemic resilience. Each indicator is evaluated and graded based on its respective values.

In this study, Smart City refers to a program promoted by the Makassar city government, known as the concept of "Sombere." In the Makassar language, "Sombere" signifies hospitality, humility, and fraternity. This concept has been culturally embedded in the utilization of digital technology (Smart) in Makassar city. The Integrated Sustainability Performance Indicators in this research are developed based on indicators according to Abu-Rayash & Dincer (2021b), where these indicators are used to test the Smart City model in Makassar city.

Data Collection

Quantitative methods were employed to design a structured questionnaire tailored to the Smart City context in Makassar. The questionnaire included variables such as environmental quality, economic vitality, social equity, and technological innovation. Data collection utilized Google Forms, email, and social media links (Instagram, Facebook, X, and WhatsApp) to distribute the questionnaire among key stakeholders, including city officials,

residents, and experts in relevant fields. Through systematic sampling techniques, a representative sample was selected to ensure the reliability and validity of the collected data. Furthermore, steps were taken to maintain ethical standards, such as obtaining participants' consent and ensuring data confidentiality. After the questionnaire distribution, the collected data underwent rigorous statistical analysis to provide input and establish relationships between various indicators. Analytical techniques such as correlation analysis, regression modeling, and factor analysis were employed to identify significant variables in the process of developing the Performance Indicator Model. The findings from the data analysis were then interpreted within the context of Smart City development.

Analisis Data

The initial modeling analysis utilized PLS-SEM to test indicators, reliability, construct formation, and model validity. Various tests were conducted to evaluate the measurement model. Measurements included Composite Reliability (CR), Cronbach's Alpha (CA), Average Variance Extracted (AVE), and Variance Inflation. Each indicator's value is recommended to be higher than 0.70 to ensure that 50% of the variance is adequately explained (Sarstedt et al., 2022). Although a threshold value of 0.70 is suggested for indicator loading, it is not recommended to remove indicators with loading values below this threshold unless the composite reliability value increases upon their removal. Therefore, the threshold value will be maintained between 0.40 and 0.70. This approach was also applied in this study (Aliedan et al., 2022; Alrawad et al., 2022; Alyahya et al., 2022).

Results and Discussion

Demographic Information

The characteristics of all participants are presented in Table 1. The majority of participants were male, comprising 120 individuals (66.6%). Most participants were under 30 years old, with 112 individuals (62.3%) falling into this age group. The dominant occupation among participants was farming, with 76 individuals (42.3%) identifying as farmers.

Table 1. Respondents' demographics

		N=180	%
Sex	Male	120	66,6%
	Female	60	33,4%
Age Range	< 30 years	112	62,3%
	30-45	36	20%
	46-40	22	12,2%
	> 60	10	5.5%
Job	PNS	13	7,3%
	Petani	76	42,3%
	Wirausaha	63	35%
	Nelayan	12	6,6%
	Lainnya	16	8,8%

Source: Primary data

Table 2. Reliability, convergent validity and multicollinearity

Factor & variables	Estimates	α	(CR)	(AVE)	(VIF)
Smart City (SC)		0.774	0.843	0.778	
SC_1	0.642				1.333
SC_2	0.784				1.783
SC_3	0.581				1.257
SC_4	0.816				1.939
SC_5	0.725				1.551
SC_6	0.657				1.183
Inclusion and Justice (IB)		0.781	0.826	0.704	
IB_1	0.816				1.202
IB_2	0.862				1.202
Telemedicine (T)		0.765	0.727	0.678	
T_1	0.762				1.153
T_2	0.512				1.073
T_3	0.769				1.093
Integrated Sustainability Performance (ISP)		0.831	0.876	0.544	
ISP_1	0.787				1.971
ISP_2	0.580				1.398
ISP_3	0.754				1.769
ISP_4	0.742				2.551
ISP_5	0.779				2.795
ISP_6	0.763				1.847

Source: Results of Smart PLS Data Analysis

Table 2 displays reliability and internal consistency figures constructed using CR and CA values. Loadings ranging from 0.727 to 0.876 indicate strong reliability of the indicators. According to Hair et al., values between 0.70 and 0.95 ensure strong reliability and validity (Liu et al., 2022). The results from Table 2 confirm that these thresholds have been met. Additionally, the Ave test to assess convergent validity also shows values above 0.50, thus meeting the recommended threshold. Lastly, VIF tests were conducted to measure the correlation of exogenous variables.

The table explains the estimation of factors and variables related to the Smart City conditions of inclusion and sustainability, telemedicine, and integrated sustainability performance. The Composite Reliability (CR) values were highest for integrated sustainability performance at 0.876, followed by Smart City at 0.843, inclusion and sustainability at 0.826, and the lowest for telemedicine at 0.727. The Average Variance Extracted (AVE) values were highest for Smart City at 0.778, while the lowest AVE value was for integrated sustainability performance at 0.544. Variance Inflation Factor (VIF) values are also presented.Composite Reliability (CR) is used to measure how well a latent variable (factor) explains the variability of related observed variables. A higher CR value indicates that the factor better explains the variability of the observed variables. Average Variance Extracted (AVE) measures the amount of variance from observed variables that can be explained by the related latent factor. A high AVE value indicates that the factor can explain a large portion of the variability of the observed variables. Finally, the Variance Inflation Factor

(VIF) is used to identify multicollinearity among independent variables in regression analysis. High VIF values indicate the presence of multicollinearity, which can affect the interpretation of the analysis results.

Table 3. Factor loadings of observables-Varimax Rotation.

Observable variables	Factorial Loads	Communality	Mean	Strt Deviation
Smart City(SC)				
SC_1	0.642	0.639	4.161	0.914
SC_2	0.784	0.777	4.183	0.806
SC_3	0.581	0.577	4.089	0.933
SC_4	0.816	0.810	4.239	0.832
SC_5	0.725	0.727	4.028	0.909
SC_6	0.557	0.545	4.000	0.913
Inclusion and Justice (IB)				
IB_1	0.816	0.814	4.194	0.803
IB_2	0.862	0.860	4.044	0.936
Telemedicine (T)				
T_1	0.762	0.752	3.944	1.172
T_2	0.512	0.494	3.500	1.204
T_3	0.769	0.775	3.489	1.167
Integrated Sustainability Performance (ISP)				
ISP_1	0.787	0.788	3.806	0.989
ISP_2	0.580	0.568	3.850	0.885
ISP_3	0.754	0.746	4.078	0.826
ISP_4	0.742	0.743	3.667	1.390
ISP_5	0.779	0.778	3.728	1.187
ISP_6	0.763	0.763	3.811	1.037

Source: Results of Smart PLS Data Analysis

The table above describes the factor loadings of the observed variables after Varimax rotation. Factor loadings measure the strength of the relationship between observed variables and latent factors that emerge after factor analysis. Higher factor loading values indicate a greater contribution of the observed variable to the factor. In addition to factor loadings, the table also includes communality values, which indicate the amount of variance in the observed variables that can be explained by the identified latent factors. Higher communality values suggest that the latent factors better explain the variation in the observed variables.The table also presents the mean and standard deviation of the observed variables. The mean represents the central value of the data distribution, while the standard deviation measures the spread of the data around the mean. This information is crucial for understanding the characteristics of the observed data. With the information provided in the table, researchers can evaluate the contribution of each observed variable to the latent factors, assess how well the latent factors explain the variation in the data, and understand the data distribution characteristics of the observed variables.

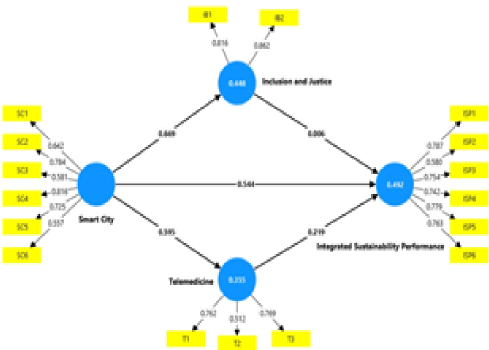
Hypothesis testing

Hypothesis testing helps researchers investigate and provide empirical evidence regarding the relationships between Smart City, inclusion and sustainability, telemedicine, and integrated sustainability performance. The results of hypothesis testing can also demonstrate how Smart City, inclusion and sustainability, and telemedicine contribute to integrated sustainability performance in the development of a city utilizing the Smart City concept.(Debata et al., 2020).

Table 4. Hypothesis testing

	Assosiation	**Coefficient (β)**	**t-value**	**p-value**	**Decision**	**R^2**	**F^2**
H1	SC→ISP	0.544	10.527	0.000	Accepted	IB= 0.448	0.274
H2	SC→ IB	0.669	10.946	0.000	Accepted	T= 0.355	0.810
H3	SC→ T	0.595	10.156	0.000	Accepted	ISP=0.492	0.549
H4	IB→ISP	0.006	0.074	0.941	Rejected		0.000
H5	T →ISP	0.219	2.714	0.007	Accepted		0.059
Specific Indirect							
H9	SC→IB→ISB	0.004	0.073	0.942	No mediation		
H10	SC→T→ISP	0.131	2.874	0.004	mediation		

Source: Results of Smart PLS Data Analysis



Source: Results of Smart PLS Data Analysis

The PLS prediction test results indicate that the majority (65%) have negative prediction values because all PLS model errors are greater than those of the LM model. Consequently, the model examining the relationships between Smart City, inclusion and sustainability, telemedicine, and integrated sustainability performance has moderate predictive strength.

Table. 5 Heterotrait-monotrait ratio (HTMT)

	SC	**IB**	**T**	**ISP**
SC				
IB	0.993			
T	0.972	0.947		
ISP	0.832	0.666	0.829	

Table 6. Cross loadings

	SC	**IB**	**T**	**ISP**
SC_1	0.642	0.365	0.307	0.621
SC_2	0.784	0.538	0.457	0.487
SC_3	0.581	0.335	0.358	0.366
SC_4	0.816	0.511	0.477	0.533
SC_5	0.725	0.538	0.481	0.401
SC_6	0.557	0.454	0.368	0.393
IB_1	0.549	0.816	0.339	0.343
IB_2	0.574	0.862	0.526	0.574
T_1	0.527	0.581	0.762	0.302
T_2	0.256	0.141	0.512	0.252
T_3	0.420	0.308	0.769	0.536
ISP_1	0.539	0.438	0.527	0.787
ISP_2	0.478	0.316	0.357	0.580
ISP_3	0.586	0.458	0.428	0.754
ISP_4	0.392	0.183	0.281	0.742
ISP_5	0.423	0.303	0.287	0.779
ISP_6	0.520	0.363	0.457	0.763

Source: Primary data

Table 6 shows that the strength between the model indicators for Smart City, inclusion and sustainability, telemedicine, and integrated sustainability performance indicates a strong need for innovative energy system development within the Smart City concept.

Discussion

Smart City in Makassar City demonstrates the importance of integrating information and communication technology to enhance inclusion and sustainability. Makassar City, as one of the major cities in Indonesia, has initiated various Smart City initiatives encompassing transportation management, energy, water, waste, and healthcare services. However, significant challenges persist in the context of inclusion and sustainability, which need to be addressed to ensure equitable benefits for all segments of society from this technology.

Inclusion in Smart City initiatives in Makassar City focuses on providing equal access to technological infrastructure and digital services for all residents, including vulnerable groups. The provision of affordable internet access and digital literacy programs is crucial to bridging the digital divide. Digital literacy programs in Makassar City need enhancement to provide training on government applications, digital healthcare services, and electronic payment systems to the community. This ensures that all residents, regardless of socioeconomic background, can actively participate in the evolving digital ecosystem.

One of the key components of Smart City initiatives in Makassar City is telemedicine. Telemedicine services are expected to improve accessibility and efficiency of healthcare services, especially for residents in remote areas and individuals with limited mobility. However, research indicates that public understanding of telemedicine in Makassar City is still limited. Many residents do not fully grasp the benefits, operational procedures, and access methods for these services. Moreover, concerns about data security and the quality of digitally provided medical services persist. Addressing these barriers requires comprehensive and intensive public education campaigns. Education on telemedicine usage, practical demonstrations, and testimonials from successful service users can help enhance public understanding and acceptance.

In terms of sustainability, Makassar City must adopt integrated sustainability performance that encompasses environmental, economic, and social aspects. Continuous evaluation of Smart City technology implementation from a sustainability perspective is crucial to ensure that technological advancements do not harm the environment or compromise social well-being. Examples include using sensors for waste management and smart transportation systems to reduce traffic congestion, demonstrating how technology can contribute to environmental sustainability. However, the success of these initiatives requires close collaboration among city governments, the private sector, and the community.

The development of policies and regulations supporting the adoption of environmentally friendly technology and integration of sustainability principles in city planning is essential for Makassar. Continuous monitoring and evaluation are necessary to ensure that Smart City technology implementation genuinely contributes positively to sustainability goals. Additionally, active community participation in the planning and decision-making process is crucial to ensure that policies align with the needs and expectations of Makassar residents.

Overall, this research underscores that achieving an inclusive and sustainable Smart City in Makassar requires a holistic approach involving various stakeholders. Government bodies, the private sector, academia, and the community must collaborate to develop technologically advanced solutions that are accessible to all and environmentally friendly. Thus, Makassar's Smart City can become a symbol of technological progress while ensuring well-being and sustainability for all residents.

Based on these findings, it is recommended that the Makassar City government enhance educational campaigns on telemedicine, especially in areas with inadequate technology access. Furthermore, improving technological infrastructure in peripheral areas should be a priority to ensure equitable access. Continuous monitoring and evaluation of Smart City implementation are needed to ensure that these initiatives truly support sustainability and inclusion, involving active participation from all segments of society. This research provides critical insights for policymakers in developing more inclusive and sustainable Smart City strategies and enhancing public understanding of digital healthcare services. With a holistic and integrated approach, Makassar City can serve as a model for successful Smart City implementation in Indonesia. Research on Smart City implementation in Makassar City indicates that the majority of participants are male, under 30 years old, and have backgrounds as farmers and entrepreneurs. The high participation from this demographic can be explained by several factors. First, males under 30 years old tend to be more active in survey and research activities due to their higher mobility and better access to communication technology. Second, backgrounds in farming and entrepreneurship indicate their involvement in economic sectors heavily reliant on technological and informational advancements, which are key elements in the Smart City concept. Farmers and entrepreneurs often seek innovative ways to enhance productivity and efficiency in their work, making them more interested and motivated to participate in research focusing on technology and sustainability. Therefore, their understanding of telemedicine and other aspects of the Smart City is crucial for further study to ensure that policies and initiatives meet the needs and expectations of the community.

Conclusion

Research on Smart City in Makassar City highlights the importance of inclusion, sustainability, and the application of technologies such as telemedicine in enhancing the quality of life for its residents. Factors such as Smart City initiatives, inclusion and sustainability efforts, telemedicine, and integrated sustainability performance show significant relationships within the context of Smart City development in Makassar. Factor analysis results indicate strong reliability with high Composite Reliability (CR) values, suggesting that latent factors effectively explain the variability of related observed variables.

This study excels in high reliability aspects, focusing on inclusion and sustainability, and emphasizing the implementation of telemedicine to improve healthcare accessibility. However, there are shortcomings in terms of unbalanced demographic participation and public understanding of telemedicine. Therefore, recommendations for future research include diversifying participant representation for better balance, conducting intensive public education campaigns on telemedicine, and developing more inclusive policies to support sustainable Smart City implementations. Consequently, future research is expected to make a greater contribution to the residents of Makassar City in achieving an inclusive and sustainable Smart City.

Author Contributions Statement

Darmawansyah; As the main author contributed to data collection, analysis and interpretation of data, apart from that the author also played a role in compiling the research manuscript and was responsible for the final completion of the article. In the final step the author gives approval to submit the research article.

Delly Mustafa, Roy G.A. Massie & Jimmy R.A Torar; Contributed to drafting the concept and designing the initial research model, the author also contributed to providing criticism and evaluation in the article writing process.

Muhammad Ahsan Samad; Contribute to the data analysis and interpretation process as well as provide revisions and intellectual input to the article writing process. Before submission, the author ensures that all research substance is in accordance with academic rules.

All authors agree to be responsible for the accuracy and integrity of the data in this article.

Conflict of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of Funding

During the preparation of this article, the authors stated that they received the budget for the publication of research results from the personal funding.

Separate Data Availability Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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