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The Impact of Smart City Dimensions on Cilegon City's Smart City Index Using SEM-PLS

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ABSTRACT

Smart city implementation requires empirical evidence on which dimensions contribute most strongly to city performance. This study examines the effects of six smart city dimensions on the Smart City Index of Cilegon City: Smart Governance, Smart Branding, Smart Economy, Smart Living, Smart Society, and Smart Environment. A quantitative design was used with 100 expert respondents from the Department of Communication and Informatics and the Regional Development Planning, Research, and Development Agency of Cilegon City. Data were collected through a structured five-point Likert questionnaire. The instrument was developed from established smart city dimensions and evaluated using convergent validity, discriminant validity, Cronbach's alpha, composite reliability, and Average Variance Extracted. The data were analyzed using Partial Least Squares Structural Equation Modeling with SmartPLS 4. The results show that Smart Governance (β = 0.187; p = 0.003), Smart Branding (β = 0.226; p = 0.005), Smart Economy (β = 0.191; p = 0.026), and Smart Society (β = 0.173; p = 0.049) have positive and significant effects on the Smart City Index. Smart Living (β = 0.135; p = 0.133) and Smart Environment (β = 0.113; p = 0.066) show positive but insignificant effects. These findings indicate that institutional, branding, economic, and social dimensions currently provide the strongest contribution to smart city performance in Cilegon City.

Keywords: *Smart City, Smart Governance, Smart Branding, Smart Economy, Smart Living, Smart Society, Smart Environment, Smart City Index*

1. INTRODUCTION

The increasing integration of digital technology into urban systems has transformed the way cities respond to complex challenges. Issues such as population growth, infrastructure limitations, and service inefficiencies require more adaptive and data-driven solutions. As a result, cities are no longer assessed solely based on physical development, but also on how effectively they leverage technology to improve governance and citizen well-being [1]. The concept of a smart city reflects this shift. Rather than focusing only on technological advancement, it emphasizes the balance between innovation, human capital, and sustainability [2]. A smart city is expected to provide efficient services, encourage community participation, and maintain environmental balance in the long term.

Despite its growing adoption, measuring the effectiveness of smart city implementation remains a challenge. Different cities apply different indicators and priorities, making it difficult to establish a universally accepted evaluation framework [3]. This creates a gap between conceptual development and empirical measurement.

In Indonesia, the "100 Smart City Movement" has been introduced to standardize the implementation of smart city initiatives. This program highlights six key dimensions that represent a comprehensive approach to urban development [4]. Cilegon City, as an industrial area, has implemented various smart city programs since 2019. However, empirical analysis on how each dimension contributes to the Smart City Index is still limited. Therefore, this study aims to analyze these relationships using the SEM-PLS approach.

2. LITERATURE REVIEW

The concept of a smart city has evolved alongside the advancement of digital technology and urban development needs. It is generally understood as an approach that integrates Information and Communication

Technology (ICT) into various aspects of city management to improve efficiency, transparency, and quality of life [1]. However, a smart city is not solely about technology. It also involves human capital, governance quality, and environmental sustainability [2]. This perspective emphasizes that technology functions as a supporting tool rather than the main objective.

To evaluate smart city performance, several frameworks have been developed. One widely accepted model divides the concept into six dimensions: Smart Governance, Smart Branding, Smart Economy, Smart Living, Smart Society, and Smart Environment [4].Previous studies show that governance and economic factors tend to have a stronger influence on smart city outcomes compared to environmental aspects [5], [6]. However, these results may vary depending on the local context and level of development.

2.1 Smart City

The concept of a smart city has evolved alongside the rapid advancement of Information and Communication Technology (ICT), which has transformed how cities manage resources and deliver public services. Initially focused on technology, the concept now emphasizes a more comprehensive approach that includes social, economic, and environmental aspects [1].

A smart city is generally defined as an urban area that utilizes technology to improve quality of life while maintaining sustainability. In this context, technology serves as an enabler that supports better governance, public participation, and efficient service delivery [2].To provide a structured framework, the smart city concept is commonly divided into six dimensions: Smart Governance, Smart Branding, Smart Economy, Smart Living, Smart Society, and Smart Environment [3]. These dimensions collectively represent the key aspects of urban development.

2.2 Smart City Index

The Smart City Index is used to measure the performance of a city in implementing smart city initiatives. It combines multiple indicators across different dimensions, such as governance, economy, environment, and society, into a single measurable value [4].

This index helps policymakers identify strengths and weaknesses, prioritize development strategies, and monitor progress over time. Additionally, it allows comparisons between cities, encouraging continuous improvement [5].However, differences in data and local context may affect the accuracy of the index, so its interpretation should consider the specific conditions of each city.

2.3 Structural Equation Modelling (SEM)

Structural Equation Modelling (SEM) is a statistical method used to analyze complex relationships between variables, including both direct and indirect effects. It allows researchers to examine multiple relationships simultaneously within a single model [6]. SEM consists of two main components: the measurement model, which evaluates validity and reliability, and the structural model, which tests the relationships between variables. This makes SEM suitable for studies involving latent variables.

2.4 Partial Least Squares (PLS)

Partial Least Squares (PLS) is a variance-based approach to SEM that is widely used in research with complex models and relatively small sample sizes. It is flexible and does not require strict assumptions such as normal data distribution [7], [9], [10]. PLS-SEM focuses on maximizing the explained variance of dependent variables, making it suitable for predictive analysis. The method involves evaluating both measurement and structural models using indicators such as reliability, path coefficients, and R-square.

3. METHOD

This study uses a quantitative approach to analyze the relationship between smart city dimensions and the Smart City Index in Cilegon City. Data were collected through questionnaires distributed to 100 expert respondents. The analysis applies SEM-PLS because the model contains several latent variables measured by multiple indicators.

3.1 Research Design

This study adopts a quantitative research design to examine the relationships between smart city dimensions and the Smart City Index in Cilegon City. A quantitative approach was chosen because it allows for systematic measurement of variables and statistical testing of hypotheses. In addition, this approach is suitable for identifying patterns and relationships between multiple variables within a structured model [6], [8], [11].

The research focuses on analyzing how each smart city dimension contributes to the overall performance of the Smart City Index. By using a structured framework, the study aims to provide empirical evidence that supports decision-making in smart city development.

3.2 Population and Sample

The population of this study consists of stakeholders involved in smart city planning, implementation, and evaluation in Cilegon City. The respondents were selected from the Department of Communication and Informatics and the Regional Development Planning, Research, and Development Agency because these institutions manage key smart city programs and policy coordination.

A total of 100 respondents were selected using purposive sampling. This technique was used to ensure that respondents had relevant knowledge of smart city implementation in Cilegon City. The sample provides expert-based institutional insight. However, because it focuses on government stakeholders, the findings should not be generalized to all citizens, private sector actors, or community groups without further research.

3.3 Data Collection Technique

Data were collected using a structured questionnaire designed to measure each variable in the study. The questionnaire was distributed directly to respondents and consisted of statements related to the six smart city dimensions and the Smart City Index.

A Likert scale was used to capture respondents' perceptions, typically ranging from strongly disagree to strongly agree. This scale allows for consistent measurement of subjective opinions and facilitates quantitative analysis. In addition to questionnaires, limited interviews were conducted to support data interpretation and provide contextual understanding of the responses.

3.4 Measurement of Variables

The research instrument was developed from established smart city dimensions in prior literature and the Indonesian smart city framework. Each construct was represented by five indicators, resulting in 35 questionnaire items. Smart Governance, Smart Branding, Smart Economy, Smart Living, Smart Society, and Smart Environment were treated as independent variables, while the Smart City Index was treated as the dependent variable [3], [11].

The Smart City Index was treated as the dependent variable, reflecting the overall performance of smart city implementation. Meanwhile, the six dimensions acted as independent variables. The use of multiple indicators for each variable allows for a more comprehensive representation of the constructs and supports the use of latent variable analysis.

4. FINDINGS AND DISCUSSION

This study uses a model consisting of seven latent variables: Smart Governance, Smart Branding, Smart Economy, Smart Living, Smart Society, Smart Environment, and the Improvement of the Smart City Index of Cilegon City. The latent variables of Smart Governance, Smart Branding, Smart Economy, Smart Living, Smart Society, and Smart Environment are exogenous variables, meaning they function as independent variables in the model. Meanwhile, the Improvement of the Smart City Index of Cilegon City is the endogenous variable, acting as the dependent variable. A total of 35 questionnaire items were used in this study, with each variable measured by five indicators. The following section presents the specification of the research model.

4.1 Model Specification

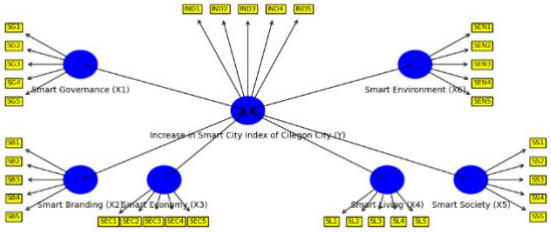


Figure 1. PLS-SEM Model.

Based on Figure 15, the model consists of seven variables with a total of 35 measurement items. Smart Governance is measured using five indicators, namely SG1, SG2, SG3, SG4, and SG5. Smart Branding is also measured by five indicators: SB1, SB2, SB3, SB4, and SB5. Similarly, Smart Economy is represented by five indicators, namely SEC1, SEC2, SEC3, SEC4, and SEC5, while Smart Living includes SL1, SL2, SL3, SL4, and SL5. Smart Society is measured using SS1, SS2, SS3, SS4, and SS5, and Smart Environment is represented by SEN1, SEN2, SEN3, SEN4, and SEN5. The Improvement of the Smart City Index of Cilegon City (Y) is measured using five indicators, namely IND1, IND2, IND3, IND4, and IND5.

4.2 Outer Loadings After Evaluation

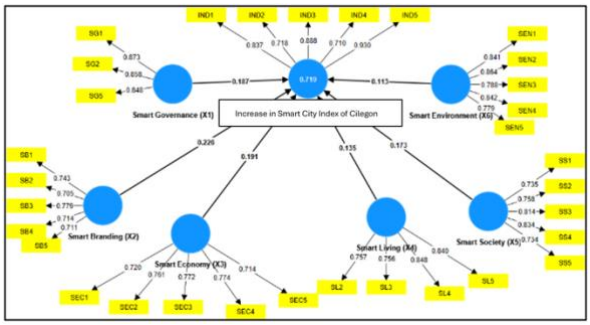


Figure 2. Outer Loadings

Based on the outer loadings values from the second run, all indicators have met the convergent validity criteria, as all values are ≥ 0.70.

4.3 Measurement Model Evaluation

Before analyzing the structural relationships, the measurement model was evaluated to ensure the validity and reliability of the constructs. Convergent validity was assessed using factor loadings and Average Variance Extracted (AVE). All indicators showed loading values above the recommended threshold, indicating that they adequately represent their respective constructs.

In addition, the AVE values for all variables exceeded the minimum requirement of 0.5, confirming that the constructs have sufficient convergent validity. Composite reliability and Cronbach's alpha values were

also above the acceptable level of 0.7, indicating good internal consistency [7], [8], [12], [13].

Discriminant validity was evaluated to confirm that each construct is empirically distinct from the other constructs. The results indicate that the six smart city dimensions and the Smart City Index measure different conceptual domains.

4.4 Structural Model Evaluation

After confirming the measurement model, the structural model was analyzed to examine the relationships between variables. The results show that Smart Governance ($\beta = 0.187$; $p = 0.003$), Smart Branding ($\beta = 0.226$; $p = 0.005$), Smart Economy ($\beta = 0.191$; $p = 0.026$), and Smart Society ($\beta = 0.173$; $p = 0.049$) have a positive and significant effect on the Smart City Index. These findings indicate that governance quality, economic capability, and social participation play an important role in shaping the performance of smart city implementation. Among these variables, Smart Branding shows the strongest influence, suggesting that the city's ability to build identity and external perception contributes significantly to its development.

On the other hand, Smart Living ($\beta = 0.135$; $p = 0.133$) and Smart Environment ($\beta = 0.113$; $p = 0.066$) show positive but statistically insignificant effects. This suggests that although these dimensions contribute conceptually, their impact is not yet strong enough to influence the Smart City Index in a measurable way. The R-square value indicates that the model explains a substantial proportion of variance in the Smart City Index, reflecting a moderate to strong explanatory power of the model [7], [8].

4.5 Discussion

The results of this study provide several important insights into the implementation of smart city initiatives in Cilegon City. First, the significant effect of Smart Governance confirms that effective public administration supported by digital systems is a key driver of smart city performance. This finding is consistent with previous studies that emphasize the importance of governance in ensuring transparency and efficiency [5].

Second, the strong influence of Smart Branding suggests that a city's image and identity play a strategic role in its development. This implies that smart city initiatives are not only about internal improvements but also about how the city positions itself externally to attract investment and public trust [6]. Furthermore, Smart Economy and Smart Society also show significant effects, highlighting the importance of economic resilience and community engagement. These dimensions reflect the role of citizens and economic actors in supporting sustainable urban development.

However, the insignificant results for Smart Living and Smart Environment indicate that these aspects may not yet be fully optimized in Cilegon City. It is possible that improvements in quality of life and environmental sustainability require a longer time to produce measurable outcomes, or that their implementation is still in the early stages. Overall, the findings suggest that institutional and socio-economic factors currently dominate smart city development, while environmental and lifestyle-related dimensions still need further attention.

5. CONCLUSIONS

The results provide several insights into smart city implementation in Cilegon City. First, the significant effect of Smart Governance confirms that public administration, digital coordination, and institutional capacity are key drivers of smart city performance. This result is consistent with recent studies that emphasize governance and interoperability as foundations of effective smart city systems [12]. Smart Branding has the strongest coefficient among the significant variables, followed by Smart Economy, Smart Governance, and Smart Society. These findings show that Cilegon City's smart city performance is mainly shaped by institutional capacity, city identity, economic activity, and social participation.

Smart Living and Smart Environment show positive but insignificant effects. This finding does not mean that both dimensions are unimportant. Instead, it indicates that their current contribution has not yet reached a statistically significant level in the model. The study has a limitation because respondents were limited to government stakeholders involved in smart city programs. Therefore, the findings should be interpreted as expert-based institutional perceptions rather than general public perceptions.

Future research should expand the sample to include citizens, private sector actors, academics, community organizations, and other urban stakeholders. A broader sample will improve generalizability and provide a more comprehensive understanding of smart city implementation in Cilegon City.

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