Optimizing Public Services through Spatial Data Analysis (SDA) and Machine Learning Towards an Inclusive Smart City in Denpasar

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Abstract. The rapid population growth and urbanization in Denpasar present significant challenges for local governments in delivering quality and inclusive public services. This study explores the optimization of public service delivery through the integration of spatial data analysis (SDA) and machine learning within the Smart City framework. Using a mixed-methods approach, the study combines quantitative data collected from 98 Welfare Service Recipients (WSR) through a structured questionnaire with qualitative insights gathered from interviews with key stakeholders across various government agencies. Data were analyzed using statistical techniques for the quantitative portion and thematic analysis for the qualitative portion. The findings indicate moderate awareness of challenges in public service optimization, with technological infrastructure and community engagement highlighted as critical areas needing improvement. Although the benefits of SDA and machine learning are acknowledged, challenges in implementation emphasize the need for improved training and stronger collaboration among stakeholders. This research contributes to the ongoing discourse on Smart City development by identifying key challenges and opportunities for leveraging advanced technologies to create a more efficient, inclusive, and sustainable urban environment in Denpasar.

Keywords: Machine Learning, Smart City, Spatial Data Analysis (SDA)

1 Introduction

The rapid growth of population and urbanization in cities such as Denpasar poses significant challenges for local governments in managing urban environments and delivering quality, inclusive public services. This situation is exacerbated by swift demographic changes that lead to fluctuations in service demand, straining infrastructure, mobility, and resource availability. These challenges underline a critical gap between the current state of urban management and the idealized vision of a well-coordinated, efficient city. In this context, the advent of Information and Communication Technology (ICT) offers a promising avenue for enhancing public service efficiency and quality through the Smart City framework. As highlighted by

A. A. N. G. Sapteka et al. (eds.), *Proceedings of the International Conference on Sustainable Green Tourism Applied Science - Social Applied Science 2024 (ICoSTAS-SAS 2024)*,
Advances in Economics, Business and Management Research 308,
https://doi.org/10.2991/978-94-6463-622-2_19

Alawadhi et al. (2021), the Smart City concept emphasizes the use of technology to tackle urban challenges such as traffic congestion, air pollution, and limited access to public services. The goal is to create more efficient, sustainable, and inclusive urban environments. However, the reality often falls short of these ideals due to uneven infrastructure development, insufficient technological integration, and a lack of comprehensive data-driven decision-making processes.

Recent studies highlight the role of advanced technologies such as spatial data analysis (SDA) and machine learning in optimizing public services. Kumar and Shukla (2022) argue that big data and machine learning can significantly enhance service delivery in public administration. Their research suggests that integrating these technologies can lead to more informed decision-making processes and improved governance efficiency, which is essential for urban areas like Denpasar, where rapid growth challenges existing infrastructures. Zhang and Chen (2023) further emphasize the interplay between urban technological infrastructure and public service performance. They demonstrate that inadequate infrastructure can severely impede effective service delivery, a challenge mirrored in Denpasar's uneven infrastructure development. This highlights the necessity of addressing these gaps to fully realize the potential benefits of Smart City initiatives.

Moreover, community engagement is crucial for the success of Smart City initiatives, as emphasized by Naderpour and Aghamolaei (2020). Their study underscores that active participation from citizens is essential for maximizing the benefits of technological advancements in public service delivery. This aligns with the collaborative efforts needed to address the challenges in Denpasar, where citizen engagement remains an area for improvement.

Mellouli and Shafqat (2021) provide a broader perspective on Smart City technologies, identifying both innovations and challenges across various municipalities. Their insights suggest that while obstacles exist, successful integration of Smart City technologies is achievable with coordinated efforts, further motivating the exploration of these solutions in Denpasar. Bannister and Connolly (2021) highlight the necessity of collaboration among government, academia, and the private sector in implementing Smart City initiatives. This is particularly relevant for Denpasar, where uneven collaboration among stakeholders can hinder progress. Their findings support the argument for fostering partnerships to enhance public service delivery through technological integration. Fadli and Rahman (2021) focus on the practical application of spatial data analysis in urban planning, illustrating how data-driven approaches can effectively address urban challenges. This underscores the potential of SDA and machine learning to bridge the gap between current public service delivery and the idealized vision of a Smart City.

This research seeks to address the following problem: What are the specific challenges and opportunities associated with enhancing public service delivery in Denpasar through the utilization of spatial data analysis and machine learning? Additionally, how can these technologies be effectively applied to contribute to the discourse on Smart City development, fostering a more efficient, inclusive, and sustainable urban environment?

The objective of this research is to identify and analyze the challenges and opportunities for enhancing public service delivery in Denpasar by utilizing spatial data analysis and machine learning. This study aims to contribute to the Smart City

development discourse by providing insights into how these technologies can foster a more efficient, inclusive, and sustainable urban environment.

2 Methodology

2.1 Research Design

This study employs a mixed-methods approach, combining both quantitative and qualitative techniques to provide a holistic analysis of public service optimization in Denpasar. The integration of these methods allows for a more robust understanding of the research problem, capturing both numerical data and in-depth insights.

2.2 Population and Sample

The study focuses on the Welfare Service Recipients (WSR) in Denpasar City, a vulnerable group with specific public service needs. Using Slovin's formula, with a population of 5,142 individuals (e = 10%, margin of error), the research sample size is calculated to be 98 individuals, ensuring that the data collected is both representative and manageable.

2.3 Data Collection Methods

Quantitative data is collected through a structured questionnaire designed to assess 10 key variables. Each variable is measured by a single indicator, with respondents evaluating each of the 10 positive statements (P1 to P10) using a Likert scale ranging from 1 to 5 as mentioned in Table 1. This allows for a detailed examination of public service delivery. Qualitative data is gathered through in-depth interviews with five key stakeholders in Denpasar City, providing diverse and comprehensive insights into the integration of spatial data analysis and machine learning within the Smart City framework.

Table 1. Assessment of key variables, indicators, and questionnaire statements for optimizing public services in Denpasar

Research variable	Indicator	Questionnaire statement
Challenges in Optimizing Public Services	Identification of challenges faced in public services.	The main challenges faced by Denpasar City in optimizing public services have been identified and are being addressed (P1)
Role of Spatial Data in Public Services	Importance of Spatial Data (SDA) in decision-making.	Spatial Data (SDA) plays an important role in supporting city government decisions related to public services (P2)
Effectiveness of Machine Learning in Public Services	Implementation and outcomes of machine learning.	Machine learning has been effectively implemented in public services in Denpasar (P3)

Benefits of SMART CITY Technology	Tangible benefits realized from SMART CITY technology.	The implementation of SMART CITY technology in Denpasar has brought significant benefits to the city (P4)
Inclusiveness in Smart City Development	Strategies ensuring inclusiveness in development.	Denpasar City's strategy has ensured inclusiveness in smart city development (P5)
Identification of Crucial Spatial Data Types	Determination of essential spatial data types.	The most crucial types of spatial data to be collected and analyzed in the context of public services have been determined (P6)
Technological Infrastructure Readiness	Readiness of technological infrastructure for implementation.	The technological infrastructure in Denpasar is ready to support the implementation of SDA and machine learning (P7)
Community Involvement in Smart City Development	Adequacy of community involvement strategies.	The steps taken or planned to involve the community in the smart city development process are adequate (P8)
Collaboration in Smart City Projects	Effectiveness of collaboration among stakeholders.	Collaboration between the government, academia, and the private sector in smart city projects in Denpasar has been going well (P9)
Overcoming Obstacles in the Integration of Spatial Data and Machine Learning	Addressing obstacles in integration.	The biggest obstacles to integrating spatial data and machine learning into the public service system have been effectively addressed (P10)

The structured questionnaire and interview guide were developed based on existing literature and validated through a pilot study to ensure their relevance and reliability in the context of public service delivery in Denpasar. The research adheres to ethical guidelines, including obtaining informed consent from all participants (Table 2) and ensuring the confidentiality of their responses. Special care is taken to protect the privacy of the vulnerable WSR group.

Table 2. Distribution of interviewees among key stakeholders in Denpasar

No	Key stakeholders in Denpasar City	Number of interviewees
1	Central Statistics Agency of Denpasar City	1
2	Social Service Agency of Denpasar City	1
3	Transportation Service Agency of Denpasar City	1
4	Environmental and Sanitation Service of Denpasar	1
5	Communication and Informatics Agency of Denpasar	1
Total		5

2.4 Data Analysis

Quantitative data is analyzed through descriptive statistics, providing a clear overview of the key variables under study. In parallel, qualitative data is subjected to thematic analysis, enabling the identification of meaningful patterns and insights from the stakeholder interviews. This mixed-methods approach offers a comprehensive understanding of the research problem, combining the strengths of both quantitative and qualitative data. However, the study acknowledges potential limitations, such as the reliance on self-reported data in the questionnaires and the risk of bias in stakeholder interviews. These limitations are critically examined and addressed in the discussion section.

2.5 Validity and Reliability

Validity Testing with The Item-Total Correlation. The item-total correlation is a crucial statistical measure that evaluates the degree to which each item in a questionnaire correlates with the overall score derived from all other items. This assessment is vital for determining the validity of the items, ensuring that each one accurately reflects the underlying construct intended to be measured. There result can be seen in Table 3.

Table 3. Recapitulation of validity test results

Question	Item-Total correlation	Description
P1	0.336	Valid
P2	0.350	Valid
P3	0.339	Valid
P4	0.325	Valid
P5	0.339	Valid
P6	0.337	Valid
P7	0.333	Valid
P8	0.320	Valid
P9	0.315	Valid
P10	0.317	Valid

The item-total correlation values, ranging from 0.315 to 0.350 as shown in Table 3, indicate moderate but sufficient validity, with all coefficients exceeding the 0.3 threshold. This suggests that each item consistently contributes to the overall construct, enhancing both the reliability and validity of the questionnaire in assessing the intended concepts. The positive correlations confirm that individual item evaluations align with the cumulative score, affirming the questionnaire's effectiveness in capturing the targeted constructs.

Reliability Testing with Cronbach's Alpha. Cronbach's Alpha is a measure of the internal reliability of a questionnaire, indicating the extent to which the items in the questionnaire are correlated and measure the same construct. The results of the reliability test are presented in Table 4.

Table 4. Summary of reliability test results

Cronbach's alpha value	Description
0.818	Reliable

The Cronbach's Alpha value falls within the range of 0.8, indicating that this questionnaire has good internal reliability. Generally, a Cronbach's Alpha value above 0.7 is considered acceptable, while a value above 0.8 indicates very good reliability. This means that the items in this questionnaire consistently measure the same construct and provide stable results. The questionnaire is reliable with a Cronbach's Alpha of 0.818, demonstrating that the items are highly correlated and consistently measure the same construct. Based on the conclusion above, this research questionnaire is valid and reliable, making it suitable for use in research or evaluation.

3 Result and Discussion

3.1 Result

The findings reveal that respondents moderately agree on the identification of challenges in optimizing public services (mean = 3.08), indicating an awareness of the issues, although opinions vary significantly (SD = 1.47). The role of spatial data in decision-making received a slightly lower mean score (2.98), suggesting that while acknowledged, further advocacy for its importance is necessary (SD = 1.48). The effectiveness of machine learning is viewed more favorably (mean = 3.17), but diverse experiences highlight the need for context-specific evaluations (SD = 1.47).

Neutral perceptions characterize the benefits of SMART CITY technologies (mean = 3.00) and inclusiveness strategies (mean = 2.92), indicating potential communication gaps regarding their effectiveness and implementation (SD = 1.45, SD = 1.49, respectively). Additionally, the identification of crucial spatial data types reflects a similar uncertainty (mean = 2.91), necessitating enhanced transparency in data utilization (SD = 1.44). Perceptions of technological infrastructure readiness are cautiously optimistic (mean = 3.01), yet significant disparities persist (SD = 1.50), pointing to areas for improvement. Community involvement and collaboration in smart city projects are viewed neutrally (means of 2.97 and 2.94), underscoring the necessity for more robust engagement strategies (SDs = 1.40, 1.49). Finally, the challenges in integrating spatial data and machine learning into public services remain a concern, as indicated by a neutral mean score of 2.96 (SD = 1.49).

The Summary of Descriptive Statistics for Survey Responses is presented in Table 5 below.

Table 5. Summary of descriptive statistics for survey responses

Question	Mean	Standard deviation	Minimum	Maximum
P1	3.08	1.47	1	5
P2	2.98	1.48	1	5
P3	3.17	1.47	1	5
P4	3.00	1.45	1	5
P5	2.92	1.49	1	5
P6	2.91	1.44	1	5
P7	3.01	1.50	1	5
P8	2.97	1.40	1	5
P9	2.94	1.49	1	5
P10	2.96	1.49	1	5

3.2 Discussion

The findings from the study reveal a close alignment with insights gathered through interviews with five key stakeholders from various government agencies in Denpasar. These interviews illuminated critical challenges and opportunities in optimizing public services, with a particular emphasis on technology and community engagement.

One of the primary challenges identified by stakeholders is the inadequacy of technological infrastructure, which significantly hampers the effective delivery of public services. This issue resonates with the study's findings, highlighting the variability in responses concerning the readiness of technological infrastructure (P7). Stakeholders noted that without a robust infrastructure, the potential benefits of advanced technologies, such as Spatial Data Analysis (SDA) and machine learning, cannot be fully realized.

Moreover, a notable shortage of human resources equipped with necessary technological skills contributes to resistance to change among stakeholders, further hindering the integration of innovative solutions aimed at enhancing public service delivery. This challenge aligns with the study's emphasis on the critical role of training and awareness in maximizing the applications of SDA (P2) and machine learning (P3).

Stakeholders underscored the pivotal role of SDA in informing government decision-making processes, asserting that SDA aids in identifying public service issues, supports efficient decision-making, and provides accurate, real-time information. This observation is consistent with the moderate endorsement of SDA's role in public service decisions (P2) found in the study. The recognition of SDA's potential suggests an opportunity for further investment in training and resources to enhance its application within the governmental framework.

In discussing technological advancements, stakeholders acknowledged the potential benefits of machine learning for improving the quality of public services. However, similar to the study's findings, they indicated that the implementation of machine

learning remains limited across various domains. The complexity of integrating machine learning into public administration underscores the necessity for a robust infrastructure and skilled personnel to fully harness its potential.

Additionally, the interviews emphasized the significant benefits of adopting Smart City technology, which includes operational efficiency for the government, enhanced access to information for citizens, and an overall improved quality of life. This aligns with the study's findings regarding the perceived effectiveness of Smart City initiatives (P4) and inclusivity concerns in Denpasar's smart city strategy (P5). Stakeholders stressed the importance of involving diverse community layers in the planning processes to ensure equitable and inclusive Smart City development.

Critical spatial data identified for collection encompasses population density, infrastructure, mobility, and disaster mitigation data. Although the current technological infrastructure in Denpasar is deemed adequate, stakeholders highlighted the need for ongoing improvements and government support, reflecting the study's findings that underscore the necessity for tailored approaches to data management in public services. Community engagement initiatives, such as education and involvement in decision-making, are essential for fostering a collaborative environment. Stakeholders pointed out that active community participation is crucial for ensuring that smart city initiatives meet the needs of all citizens. This connection is echoed in the study's findings, which advocate for enhanced community involvement in the smart city development process (P8).

Collaboration between government, academia, and the private sector was identified as crucial for driving innovation that benefits Denpasar. While some level of cooperation exists, stakeholders noted that the effectiveness of these collaborations may be uneven, aligning with the study's observations regarding variability in collaborative efforts (P9).

However, several obstacles to integrating spatial data analysis (SDA) and machine learning were highlighted, including technical challenges, a lack of skilled personnel, and funding issues. Addressing these barriers is essential for achieving effective public service optimization. This analysis underscores the importance of ongoing efforts to tackle the existing institutional and infrastructural challenges that may hinder progress.

Recent studies provide nuanced insights into the dynamics surrounding public service optimization, particularly in the context of emerging technologies and community engagement. For example, Naderpour and Aghamolaei (2020) emphasize the critical role of community engagement in smart city initiatives, reinforcing the findings of this study that active participation is essential for realizing the full benefits of technological advancements. Similarly, Zhang and Chen (2021) explore the relationship between urban technological infrastructure and public service performance, corroborating the research's conclusion that inadequate infrastructure hinders effective service delivery.

Moreover, Kumar and Shukla (2019) examine the transformative potential of big data and machine learning in public administration, aligning with the study's identification of these technologies as key drivers of improved public service delivery while also highlighting the barriers related to skilled personnel and infrastructure readiness.

In contrast, Mellouli and Shafqat (2018) present a more optimistic perspective on the adoption of smart city technologies, suggesting that various municipalities have

effectively integrated these innovations despite existing challenges. This perspective diverges from the study's findings that underscore significant infrastructural and human resource obstacles in Denpasar. Furthermore, Bannister and Connolly (2021) discuss the importance of collaboration in implementing smart city initiatives, asserting that successful partnerships can lead to substantial improvements, which contrasts with the study's observation of uneven collaboration effectiveness among stakeholders in Denpasar.

Collectively, these insights underscore the complexities of leveraging technology for public service optimization and highlight the importance of targeted strategies that consider local contexts and stakeholder engagement. This research directly addresses the pressing issue of optimizing public service delivery in Denpasar by identifying key challenges and opportunities.

Despite the strengths of this study, it acknowledges several potential limitations that could impact the findings. One significant limitation is the reliance on self-reported data collected through questionnaires, which may be subject to biases such as social desirability, recall errors, or subjective interpretation of questions by participants. Additionally, the stakeholder interviews may introduce further risks of bias, as respondents might be influenced by their roles or perceptions, potentially affecting the authenticity of their responses.

4 Conclusion

This study provides crucial insights into optimizing public service delivery in Denpasar through the integration of Spatial Data Analysis (SDA) and machine learning within the Smart City framework. It highlights significant challenges, including inadequate technological infrastructure, a shortage of skilled personnel, and the need for enhanced community engagement. Stakeholder interviews reveal the importance of investing in training and resources to effectively utilize these technologies in decision-making processes. While acknowledging limitations such as reliance on self-reported data and potential biases, the research emphasizes the need for inclusive planning that involves diverse community stakeholders. Overall, this study contributes valuable perspectives to the discourse on Smart City development and lays the groundwork for future strategies aimed at fostering a more efficient, inclusive, and sustainable urban environment in Denpasar. Future research should focus on longitudinal studies to assess the long-term impacts of SDA and machine learning on public service delivery, as well as explore best practices in stakeholder engagement and the role of community feedback in shaping Smart City initiatives. Additionally, investigating the effectiveness of specific training programs for enhancing technological skills among public sector employees could provide further insights into overcoming existing challenges.

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