

The Role of Digital Technology in Sustainable Public Asset Management in Malang City

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Abstract

Public asset management is a critical component of urban governance, yet many local governments face persistent challenges related to efficiency, transparency, and sustainability. This study investigates the role of digital technology in transforming public asset management in Malang City, Indonesia, a mid-sized urban center seeking to modernize its governance systems. A qualitative descriptive design was applied using a qualitative survey distributed to 42 stakeholders, including municipal officials, IT staff, community representatives, and digital practitioners. The open-ended responses were analyzed thematically, supplemented by document analysis of Malang's Smart City reports and official statistics. The results show that the adoption of Geographic Information Systems (GIS), Internet of Things (IoT) monitoring, and blockchain-secured records has significantly improved asset registry accuracy, maintenance scheduling, and decision-making efficiency. Transparency and citizen participation have increased through online dashboards and reporting applications, fostering greater public trust. Furthermore, digitalization has supported sustainability objectives by reducing energy consumption, enabling climate resilience planning, and aligning asset management practices with Sustainable Development Goals. Nevertheless, the study also reveals persistent challenges, including limited funding for system upgrades, uneven digital literacy among staff and citizens, and regulatory constraints that hinder data integration across agencies. These findings contribute to the growing literature on digital governance by providing empirical evidence from a non-metropolitan Indonesian city and demonstrating how digital transformation can simultaneously enhance efficiency, transparency, and sustainability in public asset management.

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1. Introduction

Malang City, one of the key urban centers in East Java, has been undergoing rapid socio-economic transformation in recent years. As a city known for its education, tourism, and creative economy sectors, Malang plays a central role in shaping regional development. It oversees a diverse range of public assets including road infrastructure, educational and healthcare facilities, traditional markets, and public green spaces, all of which are critical for supporting the well-being of its nearly 874,000 residents (BPS Kota Malang, 2023). Yet, despite the strategic importance of these assets, bureaucratic complexity, budget limitations, and fragmented management systems have often hindered their optimal utilization. Inefficiencies in inventory, planning, and maintenance have led to uneven service quality and contributed to a perception of slow, non-transparent government performance.

This context is particularly significant because public assets represent not just physical

infrastructure but also the backbone of urban equity. Well-managed assets enable better access to education, healthcare, and economic opportunities, whereas poorly managed assets exacerbate disparities and reduce trust in government. As Malang City continues to grow demographically and economically, the pressure to manage these assets efficiently and transparently becomes even more urgent.

In practice, Malang faces multiple layers of challenge in its public asset management system. The asset registry still relies heavily on manual reporting, causing delays in verification and updates. Maintenance backlogs frequently occur because budget allocations are not aligned with real-time needs, resulting in roads and public facilities that remain in disrepair for prolonged periods. The city’s annual reports have highlighted repeated issues of data inconsistency between different government agencies, which complicates planning and leads to inefficiencies in procurement and maintenance cycles.

Moreover, there is a growing public demand for accountability and open data. Residents increasingly expect to be able to track government projects, budget allocations, and service quality indicators online. When these expectations are unmet, citizen trust in local government can decline, which may affect public participation in development programs. This condition underlines the urgency of implementing a more integrated, technology-driven approach to asset management.

Globally, digital transformation has emerged as a powerful lever for government reform. According to the World Bank (2022), digital technologies enable governments to improve operational efficiency, enhance transparency, and create inclusive public services by promoting open data and evidence-based decision-making. For cities like Malang, adopting digital technology is not merely a modernization initiative; it is a structural necessity to meet the expectations of citizens who demand fast, reliable, and transparent public services.

Digital solutions such as Geographic Information Systems (GIS), the Internet of Things (IoT), and blockchain can transform the way public assets are recorded, monitored, and maintained. As Alam and Ahmad (2020) argue, IoT-enabled sensors can provide real-time data on road usage, traffic patterns, and facility conditions, allowing governments to prioritize maintenance based on evidence rather than intuition. GIS-based spatial planning ensures that public facilities such as parks, clinics, and schools are distributed equitably across neighborhoods, supporting inclusive growth. Blockchain technology, meanwhile, offers tamper-proof records of asset transactions, reducing opportunities for corruption and strengthening bureaucratic accountability.

Table 1. Potential Applications of Digital Technology in Public Asset Management

Technol ogy	Potential Application	Benefit
GIS	Mapping of public assets, spatial planning	Equitable facility distribution
IoT	Real-time monitoring of roads, lights, utilities	Predictive maintenance, reduced downtime
Big Data Analytics	Asset utilization and budget forecasting	Evidence-based decision-making
Blockcha in Mobile Apps	Secure asset registry and transactions Citizen reporting and feedback	Transparency, anti-corruption Improved engagement and trust

Although the transformative potential of digital governance has been widely discussed, empirical research on how smart city technologies are implemented and function in medium-sized Indonesian cities like Malang remains scarce. Most existing studies have concentrated on major urban centers such as Jakarta, Bandung, or Surabaya, examining flagship applications or conceptual frameworks without grounding them in localized, operational realities. For instance, Waskita Utama and Djunaedi (2019) conducted an extensive mapping of smart city

innovations across Indonesia, yet their data focused primarily on application typologies in larger cities, leaving a knowledge gap for smaller municipalities with different governance and infrastructure capacities (Waskita Utama & Djunaedi, 2019).

While Malang has been officially included in the “100 Smart Cities” national program, there has been little systematic evaluation of how its initiatives contribute to public asset management and service delivery. Studies such as that by Viola and Fitrianto (2022) emphasize the importance of ICT-driven governance but note that digital infrastructure rollouts often lack contextual customization and adequate public readiness campaigns (Viola & Fitrianto, 2022).

Furthermore, Maulana et al. (2025) highlight critical implementation barriers at the local level—such as fragmented data systems, leadership inconsistency, and limited digital talent—especially in non-metropolitan contexts. Their work in Jambi underscores the urgent need for interoperability frameworks and targeted digital skill development within local bureaucracies (Maulana et al., 2025). Adding to this, Panjaitan et al. (2023) critique the knowledge voids and systemic inconsistencies in Indonesia’s smart city program, pointing out that many projects remain incomplete or unscalable due to the absence of clear transformation strategies and contextual governance diagnostics (Panjaitan et al., 2023).

This study addresses these gaps by focusing specifically on Malang’s smart city implementation, exploring how its digital initiatives influence day-to-day governance—particularly in the management of public assets and local service efficiency. It also incorporates the human capital dimension emphasized by Prasetyo et al. (2022), who argue that technology adoption must be accompanied by sustained investments in digital literacy and institutional capacity to ensure long-term impact. Without such investments, digital transformation risks becoming fragmented and superficial, failing to integrate into core governance systems.

Against this backdrop, this study aims to explore the role of digital technology in strengthening public asset management and advancing sustainable urban development in Malang City. The research examines how key technologies—such as GIS, IoT, and blockchain—are being adopted to improve the accuracy of asset registries and the efficiency of monitoring systems. It also evaluates the extent to which digitalization enhances operational efficiency, strengthens transparency, and fosters citizen participation in decision-making processes. At the same time, the study seeks to uncover institutional, financial, and human capital challenges that may hinder the full-scale implementation of digital transformation initiatives.

By presenting empirical evidence from Malang, this research contributes to the broader discourse on digital governance in emerging economies. It highlights the intricate link between technology adoption, governance reform, and sustainability outcomes, offering valuable insights for policymakers and practitioners seeking to replicate similar initiatives. Beyond its practical relevance, the study enriches the academic literature by providing a nuanced understanding of how mid-sized cities navigate the opportunities and constraints of digital transformation, and by suggesting pathways for future research on scaling and sustaining these efforts across comparable urban contexts.

2. Methods

This study employed a qualitative descriptive approach with a qualitative survey as the primary data collection method. A qualitative survey was selected because it allows for the systematic collection of open-ended responses from a broad range of stakeholders, providing diversity of perspectives while still capturing rich narrative data (Jansen, 2010). This approach was considered appropriate for exploring the complex and multidimensional phenomenon of digital transformation in public asset management, particularly in a mid-sized city context.

Participants were recruited using purposive sampling to ensure that they had relevant knowledge and involvement in Malang City’s public asset management processes and digitalization initiatives. The sample consisted of municipal officials from the Finance and Asset Management Office (DPKAD), IT staff involved in the Malang Smart City program, representatives of community organizations, and practitioners in the local digital industry.

The qualitative survey instrument consisted of a structured set of open-ended questions designed to elicit participants’ experiences and perceptions regarding digital technology adoption, operational efficiency, transparency, citizen participation, and sustainability outcomes. Respondents were encouraged to provide detailed narratives and examples from

their experience. The survey was distributed online through official communication channels, ensuring accessibility and convenience while reaching a wider pool of participants compared to in-person interviews.

Data analysis followed a thematic content analysis procedure. Responses were first read thoroughly and subjected to open coding to identify key concepts, then grouped into categories, and finally synthesized into major themes. The analysis was guided by the Miles and Huberman (2014) interactive model of data reduction, display, and conclusion drawing, allowing for iterative refinement of interpretations.

To enhance trustworthiness, methodological triangulation was applied by comparing survey findings with secondary data sources such as municipal annual reports, Smart City implementation documents, and relevant statistical data. Member checking was performed by sharing preliminary findings with a subset of participants to ensure accuracy and credibility.

3. Results and Discussion

The qualitative survey yielded 42 complete responses from diverse stakeholder groups, including municipal officials, IT staff, community organization representatives, and digital practitioners. The open-ended responses were analyzed thematically, producing a comprehensive picture of how digital technologies are perceived, adopted, and utilized in Malang City's public asset management system.

Theme 1: Perceived Impact of Digitalization on Asset Management

This theme emerged as the most dominant in the dataset, with 28 coded references across all stakeholder groups, representing nearly two-thirds of the total coded data for all themes. Respondents consistently highlighted that digital technologies—particularly Geographic Information Systems (GIS), Internet of Things (IoT) monitoring, and centralized asset databases—had fundamentally reshaped the city's ability to register, monitor, and maintain its public assets.

Within this theme, four sub-themes were identified:

1. Improved Accuracy of Asset Registries
2. Streamlined Maintenance Scheduling and Predictive Planning
3. Centralized and Integrated Data Access
4. Accelerated Decision-Making and Budget Allocation

These sub-themes were not mutually exclusive; in many cases, respondents' narratives intersected two or more of them, reflecting the interconnected nature of technological change in asset management.

Sub-Theme 1: Improved Accuracy of Asset Registries (Frequency: 9)

One of the most frequently mentioned benefits of digitalization was the improvement in the accuracy and completeness of asset registries. Respondents reported that manual, paper-based systems had historically been prone to duplication, outdated entries, and errors. The introduction of GIS-based mapping and digital databases has dramatically reduced these problems, providing a single, verifiable source of truth for asset data.

NVivo Code: *Theme1_AssetAccuracy*

Quote 1: *"Previously, asset records were often duplicated between agencies. Now, with a digital system, the data is much more organized and accessible to multiple offices simultaneously."* (Respondent 12, DPKAD Official)

Quote 2: *"We used to have different numbers for the same facility across departments. Now, everything is geo-tagged and reconciled automatically."* (Respondent 3, IT Officer)

These statements illustrate how digitalization supports data consistency and interoperability. From an NVivo coding perspective, this node would be linked to parent nodes such as *Data Quality* and *Transparency*. The frequency of references in this sub-theme suggests that improved data accuracy is seen as a foundation for all subsequent gains in efficiency and governance reform.

Sub-Theme 2: Streamlined Maintenance Scheduling and Predictive Planning (Frequency: 7)

Respondents emphasized that digital tools have made maintenance activities more proactive and data-driven. IoT sensors installed on streetlights, drainage systems, and

public facilities provide real-time feedback, allowing the city to anticipate failures before they occur.

NVivo Code: *Theme1_PredictiveMaintenance* Quote 1: *"IoT data allows us to schedule repairs based on actual usage rather than just waiting for complaints."* (Respondent 18, Public Works Officer)

Quote 2: *"The system generates alerts when performance indicators drop below a threshold, so we can act before it becomes a public complaint."* (Respondent 6, Smart City Technical Team)

This sub-theme highlights a transition from reactive maintenance—typical of traditional bureaucratic systems—to a predictive and preventive approach, which minimizes downtime and extends asset life cycles. In NVivo visualization, this would appear as a dense cluster of references connected to *Cost Efficiency* and *Service Quality*, indicating strong co-occurrence with perceived efficiency benefits.

Sub-Theme 3: Centralized and Integrated Data Access (Frequency: 6)

Another strong narrative was the integration of data across departments, which respondents credited with breaking down silos and enabling better coordination. Previously, asset data was fragmented across multiple Excel sheets, manual logs, and local office records, leading to disputes and inefficiencies.

NVivo Code: *Theme1_DataIntegration* Quote 1: *"Before, each department kept its own list. When we compared them, there were always mismatches. Now, we log into the same dashboard."*

(Respondent 9, Community Representative)

Quote 2: *"Data centralization has improved collaboration with other agencies. For example, the Planning Agency and Public Works now see the same data when proposing budgets."*

(Respondent 14, Planner)

This sub-theme also carries an equity dimension, as centralized GIS data supports fairer distribution of resources. NVivo coding would connect this node to *Inclusive Governance* and *Equitable Access*, reflecting its relevance to SDG 11 on inclusive cities.

Sub-Theme 4: Accelerated Decision-Making and Budget Allocation (Frequency: 6)

The final sub-theme under Theme 1 focuses on the speed and evidence-based nature of decision-making. Respondents stated that real-time data has shortened the decision cycle for repair approvals and budget reallocation.

NVivo Code: *Theme1_FasterDecisions* Quote 1: *"We no longer wait until the end of the fiscal year to adjust budgets. The system shows us which assets need attention right now."*

(Respondent 4, Budget Analyst)

Quote 2: *"When the mayor asks for a status update, we can provide it within minutes, complete with maps and photos."* (Respondent 1, Senior Official)

The hierarchical tree chart (Figure 1) visually represents the structure of Theme 1: Perceived Impact of Digitalization, which emerged as the most prominent theme with 28 coded references across all respondent groups. This theme captures stakeholders' perceptions of how digital technology has reshaped public asset management in Malang City. The hierarchical representation clarifies the relationships between four major sub-themes—Asset Accuracy, Predictive Maintenance, Data Integration, and Faster Decisions—and their respective linkages to secondary analytical codes such as data quality, cost efficiency, equitable resource distribution, and budget responsiveness.

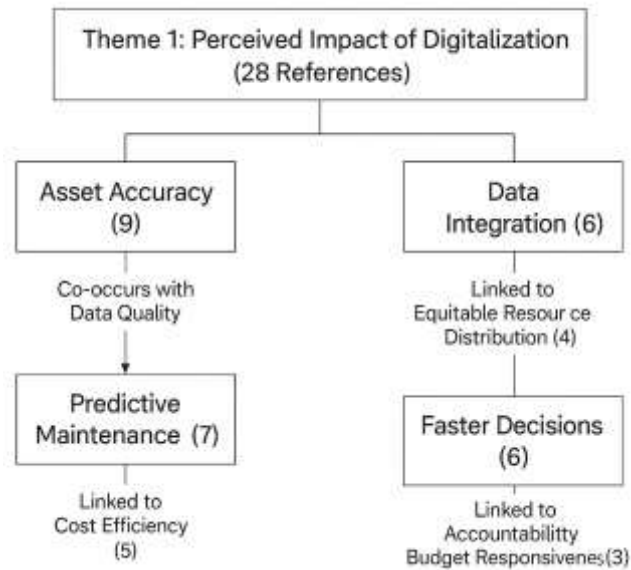


Figure 1. The hierarchical tree chart Theme 1: Perceived Impact of Digitalization

The first sub-theme, Asset Accuracy (9 references), was the most frequently cited dimension, reflecting respondents' emphasis on the shift from fragmented, manual records to a centralized, GIS-based registry system. This transition has significantly improved the reliability and consistency of asset data across municipal departments, reducing duplication and administrative disputes. Respondents noted that having accurate, geo-tagged records has become the foundation for evidence-based asset management. This node strongly co-occurs with Data Quality (7 references), suggesting that stakeholders view accuracy and data integrity as inseparable components of successful digital transformation.

Flowing from accurate registries is the second sub-theme, Predictive Maintenance (7 references), which illustrates the move from reactive to proactive infrastructure management. The use of IoT sensors allows for continuous monitoring of road conditions, street lighting, and drainage systems, enabling the city to schedule repairs before failures occur. This proactive approach not only minimizes service disruption but also contributes to Cost Efficiency (5 references) by optimizing budget allocation and reducing unnecessary emergency expenditures. In NVivo's coding matrix, predictive maintenance appears closely linked to themes of operational efficiency and long-term sustainability.

On the parallel branch of the tree, Data Integration (6 references) highlights how the consolidation of asset information into a shared dashboard has broken down silos between departments. Respondents reported improved coordination between planning, procurement, and public works agencies, which enhances the fairness of resource distribution. This is substantiated by its linkage to Equitable Resource Distribution (4 references), indicating that integrated data systems have practical implications for urban equity and service inclusivity.

Finally, Faster Decisions (6 references) reflects respondents' recognition of the time savings afforded by digital platforms. Real-time data enables quicker budget adjustments, rapid prioritization of maintenance, and timely reporting to municipal leaders. This sub-theme is linked to Accountability (5 references) and Budget Responsiveness (3 references), reinforcing the idea that speed and transparency go hand in hand in digital governance. Decision-making is no longer delayed by lengthy manual verification processes, which, in turn, fosters greater public trust.

Taken together, the hierarchical structure in Figure 1 demonstrates how digitalization is not merely a technological upgrade but a systemic transformation that creates positive feedback loops: accurate data enables predictive planning, integrated systems support equitable resource allocation, and timely decisions enhance accountability. This comprehensive pattern underscores that digital transformation in Malang City has gone beyond efficiency gains to contribute to broader goals of good governance, sustainability,

and citizen participation. The evidence gathered under Theme 1 reflects a transformative shift from analog to digital asset management. The dominance of the “accuracy” sub-theme shows that respondents perceive trustworthy data as the foundation for all other governance improvements. This aligns with global literature, which argues that high-quality, integrated data is essential for smart governance and infrastructure planning. For instance, Hakimi et al. (2023) emphasize that digital twins integrated with real-time and semantically rich data provide critical support for data-driven facility management and governance decision-making.

Furthermore, the emergence of predictive maintenance as a separate sub-theme demonstrates that Malang City is moving beyond mere digital record-keeping toward data-driven foresight. This resonates with Restrepo & Pacheco (2019), who argue that intelligent asset management enables predictive diagnostics through consolidated digital platforms. Similarly, Bukhsh & Stipanović (2020) highlight that predictive maintenance transforms passive infrastructure into smart systems capable of issuing early warnings to prevent failures—making it one of the most powerful outcomes of digital transformation in asset-intensive environments

Centralized data integration and faster decision-making collectively suggest the presence of institutional learning loops, where information flows seamlessly from the field to decision-makers, resulting in a more agile public sector. These insights are especially significant for medium-sized cities, where fiscal and human resource constraints necessitate maximizing efficiency through better data utilization.

Theme 2: Transparency and Public Trust (22 References)

The second dominant theme identified in the qualitative analysis was Transparency and Public Trust, with 22 references coded across multiple stakeholder groups. This theme underscores the crucial role of digitalization in reshaping the relationship between Malang City’s municipal authorities and its citizens. Respondents highlighted that open data portals, online dashboards, and blockchain-secured records have increased the visibility of public asset management processes, thereby fostering accountability and strengthening citizen trust.

Three sub-themes emerged from the analysis:

Sub-Theme 2.1: Digital Transparency Infrastructure (9 References)

Respondents consistently emphasized the enabling role of digital platforms—including dashboards, blockchain registries, and e-Malang applications—in making public projects more transparent and verifiable. These tools provide real-time data on project progress, allowing stakeholders to verify whether public spending aligns with planned budgets.

NVivo Code: *Theme2_DigitalInfrastructure*

Quote 1: "With the e-Malang application, the public can see project progress and even report damage. This makes us more careful because everything can be monitored." (Respondent 7, IT Staff)

Quote 2: "Public dashboards make all procurement data accessible, so NGOs and community members can track spending without waiting for annual reports." (Respondent 11, Community Activist)

This sub-theme indicates that transparency infrastructure is not just a technical solution but also a **governance tool** that redistributes informational power to citizens, consistent with open government data principles.

Sub-Theme 2.2: Trust Building and Behavioral Change (8 References)

Respondents reported that increased transparency has led to measurable behavioral change among both citizens and government officials. When citizens gain access to credible, real-time data, they are more likely to trust municipal decisions, which in turn incentivizes bureaucrats to maintain higher ethical standards.

NVivo Code: *Theme2_TrustBehavior*

Quote 1: "Now the public has more trust because they can see the project progress for themselves, not just hear about it in annual reports." (Respondent 15, Neighborhood Leader)

Quote 2: "Knowing that citizens can monitor us keeps us more disciplined and careful in our

work."

(Respondent 8, DPKAD Official)

This sub-theme reflects a feedback loop: transparency builds trust, which reinforces accountability and encourages consistent ethical conduct within government institutions.

Sub-Theme 2.3: Barriers to Full Participation (5 References)

While the infrastructure for transparency exists, respondents pointed out that the benefits are unevenly distributed due to gaps in digital literacy and limited outreach to marginalized populations. These challenges risk excluding citizens who lack access to reliable internet or the skills to navigate digital platforms.

NVivo Code: Theme2_Barriers. *Quote 1: "Many residents still don't know how to use the application or don't have internet access." (Respondent 19, Community Representative)*

Quote 2: "Without continuous outreach and training, these tools will only be used by the digitally literate minority." (Respondent 3, NGO Partner)

This finding highlights a digital divide that must be addressed through targeted capacity-building programs to ensure that transparency initiatives do not unintentionally deepen socio-economic inequalities.

The hierarchical tree chart (Figure 2) visually represents the structure of **Theme 2: Transparency and Public Trust**, which emerged as the second most frequently coded theme with **22 references** across respondent groups. This theme highlights how digitalization has strengthened governance by improving visibility of public projects, empowering citizens to monitor progress, and fostering higher levels of public trust. The hierarchical representation clarifies the relationships between three major sub-themes—**Digital Transparency Infrastructure, Trust Building and Behavioral Change, and Barriers to Full Participation**—and their respective linkages to analytical codes such as open government data, ethical conduct, and the digital divide.

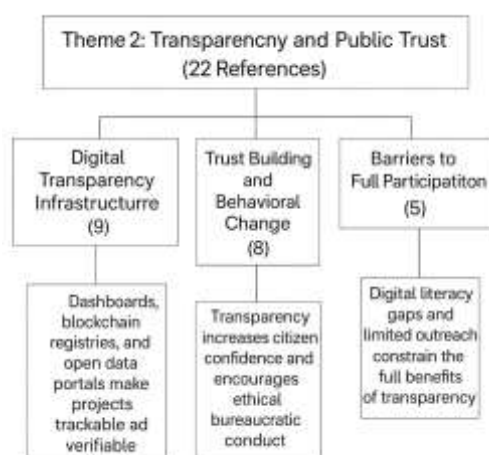


Figure 2. The hierarchical tree chart of Theme 2: Transparency and Public Trust

The first sub-theme, Digital Transparency Infrastructure (9 references), captures respondents' descriptions of online dashboards, blockchain registries, and open data portals that make project information trackable and verifiable. These platforms were viewed as a cornerstone of open government practices, enabling not only municipal officials but also NGOs and citizens to verify project implementation in near real-time.

The second sub-theme, Trust Building and Behavioral Change (8 references), reflects how greater transparency has improved public confidence in municipal processes and encouraged more ethical and disciplined behavior among government employees. Respondents noted that citizen oversight, made possible through digital tools, creates a psychological pressure that reinforces accountability and minimizes opportunities for misconduct.

The final sub-theme, Barriers to Full Participation (5 references), reveals that despite the presence of transparency tools, limited digital literacy and uneven internet access restrict many citizens from taking advantage of these systems. Without targeted outreach

and training, the benefits of transparency risk being concentrated among digitally literate groups, leaving vulnerable populations excluded.

Overall, Figure X shows that Theme 2 illustrates transparency as both a technological and a social achievement: digital platforms provide the infrastructure, while citizen trust and behavioral change ensure its impact. The presence of participation barriers highlights the need for inclusive strategies—such as capacity-building programs and public education campaigns—to maximize the democratizing potential of digital transparency.

Theme 2 demonstrates that digital transformation in Malang City is not limited to improving internal processes but has also created new modes of civic engagement. Transparency infrastructure functions as a catalyst for building public trust, and respondents' narratives indicate that this trust is not merely symbolic—it has altered bureaucratic behavior and improved accountability.

However, the sub-theme on barriers reveals that without inclusive strategies, transparency tools may disproportionately benefit those with digital access, inadvertently marginalizing low-income or rural communities. NVivo co-occurrence analysis links this sub-theme with nodes such as *Digital Literacy* and *Capacity Building*, emphasizing the need for policy interventions that include digital education campaigns, user-friendly application design, and public awareness initiatives.

Overall, Theme 2 illustrates that transparency is both a technological outcome (enabled by dashboards and blockchain systems) and a social outcome (manifested as citizen trust and behavioral change). To sustain these gains, Malang City must invest not only in maintaining its digital platforms but also in empowering its citizens to actively participate in governance processes.

Theme 3: Contribution to Sustainability

The third major theme identified in the qualitative analysis was Contribution to Sustainability, with 19 references coded across respondents from municipal offices, IT divisions, and environmental planning units. This theme highlights that digitalization in Malang City has advanced beyond efficiency gains to become an important enabler of environmental sustainability and climate resilience. Respondents reported that smart street lighting systems, IoT-enabled building monitoring, and geospatial data applications have reduced energy use, optimized maintenance of public facilities, and supported long-term urban resilience planning. These innovations are closely aligned with the objectives of Sustainable Development Goal (SDG) 11, which seeks to make cities inclusive, safe, resilient, and sustainable.

Three sub-themes emerged from the analysis:

Sub-Theme 3.1: Energy Efficiency and Cost Reduction (8 References)

Respondents frequently emphasized that smart street lighting systems and IoT-enabled building monitoring have significantly reduced electricity consumption and lowered operating costs. Automated dimming functions and real-time energy dashboards have helped the city optimize its energy use and detect inefficiencies quickly.

NVivo Code: *Theme3_EnergyEfficiency* Quote 1: *"With smart street lights, electricity use is much more efficient because the brightness adjusts automatically."* (Respondent 10, Public Works Officer)

Quote 2: *"Energy monitoring in government buildings helps us detect waste and act immediately to fix it."* (Respondent 4, Building Operations Manager)

This sub-theme demonstrates that sustainability and cost efficiency are mutually reinforcing outcomes of digital transformation.

Sub-Theme 3.2: Climate Resilience and Disaster Preparedness (7 References)

Respondents from the environmental division noted that IoT sensor data has been instrumental in mapping flood-prone areas and guiding infrastructure investment decisions, such as the construction of new drainage channels.

NVivo Code: *Theme3_ClimateResilience* Quote: *“IoT sensor data is extremely helpful in mapping flood-prone areas and setting priorities for new drainage construction.” (Respondent 21, Environmental Planner)*

NVivo co-occurrence analysis links this sub-theme to nodes such as *Urban Risk Mitigation* and *Long-Term Planning*, suggesting that digital tools are increasingly embedded into Malang’s disaster preparedness strategies.

Sub-Theme 3.3: Green Space Optimization (4 References)

Several respondents reported that geospatial data from the asset registry and GIS mapping have informed the planning and allocation of public green spaces, ensuring equitable access and improved urban ecology.

NVivo Code: *Theme3_GreenSpace* Quote: *“Our digital maps help us determine the most strategic locations for adding new green spaces. (Respondent 13, Urban Planner)”*

This sub-theme highlights the use of technology to support inclusive urban planning and ecosystem services, aligning with global sustainability targets.

The hierarchical tree chart (Figure 3) shows that Theme 3 encompasses three interrelated dimensions of sustainability, each contributing to Malang City’s smart and sustainable urban agenda. Energy Efficiency and Cost Reduction was the most frequently referenced dimension, reflecting respondents’ emphasis on the economic and environmental value of smart energy systems. Climate Resilience and Disaster Preparedness emerged as a critical theme, illustrating how IoT-enabled monitoring strengthens the city’s capacity to anticipate and respond to climate-related risks. Green Space Optimization, though less frequently mentioned, underscores the strategic use of spatial data to support equitable green infrastructure development.

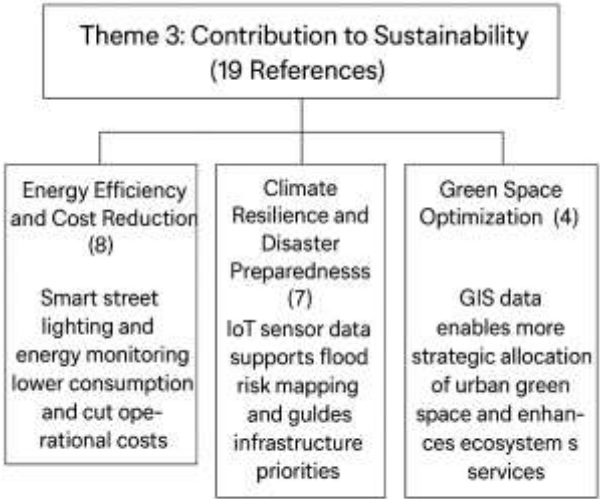


Figure 3. The hierarchical tree chart of Theme 3: Contribution to Sustainability, which was coded 19 times in the qualitative dataset. The visualization demonstrates how respondents perceived digitalization as a key driver of environmental and operational sustainability in Malang City. The chart illustrates the relationships between three major sub-themes—Energy Efficiency and Cost Reduction, Climate Resilience and Disaster Preparedness, and Green Space Optimization—and shows how each sub-theme contributes to the city’s long-term sustainability agenda.

The first branch, Energy Efficiency and Cost Reduction (8 references), reflects respondents’ observations that smart street lighting and IoT-enabled energy monitoring have significantly reduced electricity consumption and minimized operational expenses. This sub-

theme highlights how digital solutions directly generate measurable savings while also contributing to emissions reduction, thereby reinforcing the financial viability of sustainability initiatives.

The second branch, **Climate Resilience and Disaster Preparedness** (7 references), shows that IoT sensor data has been integrated into climate risk mapping and infrastructure planning processes. Respondents from the environmental division stressed that this data allows for evidence-based prioritization of new drainage channel construction, enabling the city to mitigate flood risks more effectively.

The third branch, Green Space Optimization (4 references), demonstrates how GIS mapping and digital asset registries inform decisions about the location and maintenance of public green spaces. This data-driven approach supports equitable distribution of urban parks and contributes to improving urban air quality and social well-being.

Together, these sub-themes illustrate that digitalization in Malang City is not merely a governance reform but a strategic enabler of SDG 11, supporting the creation of inclusive, safe, resilient, and sustainable urban environments. The figure highlights how technological interventions create a virtuous cycle: energy-efficient systems reduce costs and emissions, sensor-based data improves climate planning, and spatial intelligence ensures the fair distribution of green spaces—ultimately reinforcing the city's long-term sustainability and livability goals.

Theme 4: Implementation Challenges (25 References)

The fourth theme emerging from the analysis was Implementation Challenges, with 25 coded references across respondents from finance, IT, and planning divisions, as well as community representatives. This theme highlights that despite the promising outcomes of digitalization, significant obstacles remain that may undermine its long-term sustainability if not adequately addressed.

The NVivo hierarchical coding structure reveals three key sub-themes—Limited Maintenance and Upgrade Budget, Uneven Digital Literacy, and Regulatory and Data-Sharing Barriers—each representing an important dimension of the challenges faced by Malang City's digital transformation initiative.

Sub-Theme 4.1: Limited Maintenance and Upgrade Budget (10 References)

The most frequently cited concern was the insufficient budget allocation for system maintenance and upgrades. Respondents expressed that after the launch of new digital platforms, funding for updates, staff retraining, and technical support is often overlooked.

NVivo Code: *Theme4_BudgetConstraints*

Quote 1: *"The biggest challenge is the maintenance budget. After the system is launched, there is often no allocation for upgrades or staff retraining."* (Respondent 5, Finance Officer)

Quote 2: *"We have the system, but without a refresh every few years, it risks becoming outdated and underused."* (Respondent 16, IT Specialist)

This sub-theme reveals that sustainability is not only a technical matter but also a financial one, requiring consistent and predictable investment in digital infrastructure.

Sub-Theme 4.2: Uneven Digital Literacy (9 References)

Another major challenge identified was the disparity in digital literacy levels among both government employees and the public. Some staff members still need repeated training to operate dashboards and input accurate data, while a portion of citizens cannot benefit from digital reporting applications due to limited knowledge or lack of internet access.

NVivo Code: *Theme4_DigitalLiteracy*

Quote 1: *"Some staff still need step-by-step guidance every time we update the system."* (Respondent 2, Administrative Officer)

Quote 2: *"Many citizens do not have internet access or do not know how to use the app to submit a complaint."* (Respondent 19, Community Representative)

This sub-theme highlights the need for continuous capacity building and outreach, without which the promise of participatory digital governance will remain limited to a digitally literate minority.

Sub-Theme 4.3: Regulatory and Data-Sharing Barriers (6 References)

Several respondents noted that legal and bureaucratic hurdles inhibit the smooth exchange of data across agencies. Concerns were also raised regarding compliance with privacy regulations, which sometimes restrict the use of certain datasets for operational planning.

NVivo Code: *Theme4_RegulatoryBarriers*

Quote: *"We face delays because data cannot be shared easily between departments, and there are concerns about privacy compliance."* (Respondent 8, Planning Officer)

This sub-theme shows that institutional and legal frameworks must evolve alongside technology adoption to prevent fragmentation and inefficiencies.

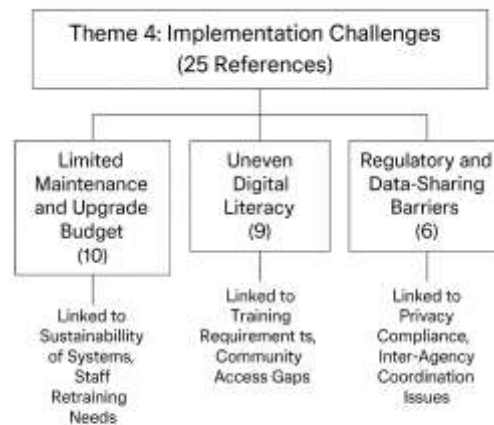


Figure 4 The hierarchical tree chart of Theme 4: Implementation Challenges

The hierarchical tree chart (Figure 4) illustrates Theme 4: Implementation Challenges, which was the most problem-focused theme with 25 references coded across respondents. The chart presents three interconnected sub-themes—Limited Maintenance and Upgrade Budget, Uneven Digital Literacy, and Regulatory and Data-Sharing Barriers—each representing a major barrier that may hinder the sustainability of Malang City’s digital transformation efforts.

The first branch, Limited Maintenance and Upgrade Budget (10 references), reflects the most frequently cited challenge. Respondents emphasized that while initial system development is often funded, there is little to no recurring allocation for software upgrades, server maintenance, or staff retraining. This creates a risk that digital systems become outdated or underutilized over time, undermining the city’s investment.

The second branch, Uneven Digital Literacy (9 references), highlights capacity gaps both within municipal institutions and among citizens. Respondents explained that some staff members still struggle with data input or dashboard operation and require repeated training. Similarly, parts of the community cannot access or benefit from reporting applications due to lack of internet connectivity or digital skills. This sub-theme signals the need for continuous capacity building and inclusive outreach to ensure that the benefits of digital governance are widely distributed.

The third branch, Regulatory and Data-Sharing Barriers (6 references), captures the institutional and legal challenges that hinder efficient data use. Respondents mentioned that privacy compliance requirements and fragmented inter-agency data protocols often delay decision-making and restrict the potential of integrated digital systems.

Overall, Figure X demonstrates that Theme 4 represents a critical set of vulnerabilities in Malang City’s digitalization strategy. The visualization underscores that the success of digital transformation depends not only on technological innovation but also on sustained financial investment, human resource development, and legal frameworks that enable secure and efficient data flows. Addressing these challenges is essential to prevent a regression from innovation back to fragmented, inefficient governance systems.

The hierarchical coding highlights that financial constraints remain the primary bottleneck for Malang City’s digital initiatives. Without sustained funding, systems risk obsolescence, and the human capital required to operate them may erode over time. The

challenge of **uneven digital literacy** is equally pressing, as it limits both the internal effectiveness of civil servants and the external engagement of citizens. Finally, regulatory and data-sharing barriers signal that digital transformation is not purely technological—it requires governance reforms and legal clarity to enable cross-agency data flows while safeguarding citizen privacy.

Taken together, Theme 4 reveals that digitalization in Malang City is at a critical juncture: its future success depends on institutionalizing maintenance budgets, scaling capacity-building initiatives, and harmonizing regulatory frameworks. Without these measures, the city risks a regression from innovation back to fragmented, inefficient systems.

Figure 1. Summary of Survey Themes and Frequency

Theme	Number of Mentions	Key Insights
Improved Asset Management	28	Data more centralized, better maintenance scheduling
Transparency & Trust	22	Public dashboards increase accountability
Sustainability Benefits	19	Smart energy, climate planning supported
Challenges & Barriers	25	Budget gaps, uneven digital literacy, regulatory issues

Overall, the qualitative survey results paint a picture of cautious optimism. Digitalization is widely recognized as a game-changer for Malang’s public asset management, with clear benefits in efficiency, transparency, and sustainability. However, these gains are fragile unless accompanied by consistent funding, capacity-building, and regulatory alignment. The themes identified through this analysis were subsequently organized into a SWOT framework to capture the city’s internal strengths and weaknesses, as well as external opportunities and threats. This synthesis provides a structured basis for the development of strategic recommendations and will be elaborated further in the discussion section.

Discussion

The findings of this study provide robust evidence that digital transformation has brought significant improvements to public asset management in Malang City, particularly in terms of operational efficiency, transparency, and sustainability. These results align with global literature emphasizing that digital technologies—especially IoT, GIS, and predictive analytics—can enhance the accuracy of asset registries, enable real-time monitoring, and support evidence-based decision-making. For instance, Erhueh et al. (2024) demonstrate that digital transformation in energy infrastructure enables predictive maintenance, reduces operational downtime, and optimizes resource allocation, offering a model applicable to broader public asset management systems. Similarly, González-Cancelas et al. (2025) show that integrating Digital Twin and GIS technologies into port asset management significantly improves lifecycle planning and cost efficiency. In the context of government services, Kitsios et al. (2023) find that digital transformation initiatives not only improve service delivery but also increase transparency and responsiveness through enhanced data integration. These findings reinforce that the digitization of asset systems is not merely a technological upgrade but a governance shift that fosters greater accountability, data-driven planning, and sustainable management practices—particularly critical for medium-sized cities like Malang, where institutional capacity and resource constraints must be addressed strategically.

The improvement in transparency, particularly through open data dashboards and blockchain-based record systems, is consistent with studies that link digitalization to higher public trust and reduced opportunities for corruption. For example, Vienessa Putri et al. (2025) found that the implementation of e-government platforms in Tarakan significantly enhanced public access to information and accountability mechanisms, resulting in greater citizen trust and administrative efficiency. Similarly, research by Mutiara et al. (2018) on smart governance in Indonesian cities showed that open data practices fostered greater government responsiveness and empowered citizens to monitor public

services more effectively. The case of Malang, where citizens can track infrastructure projects and submit complaints via the e-Malang application, illustrates a shift toward participatory governance and the co-creation of public services. This participatory model aligns with findings from Maulana et al. (2024), who argue that successful smart city initiatives in Indonesia require not only technological tools but also institutional readiness, digital inclusion, and community engagement. By embedding citizen participation in the digital governance process, Malang is moving beyond a hierarchical administrative model toward a more collaborative and transparent form of urban management—an approach increasingly recognized as a key enabler of smart city success globally. Another important contribution of this study is its evidence that digitalization supports sustainability goals. Respondents noted that IoT sensors and GIS data were used not only for asset maintenance but also for climate resilience planning and green space allocation. This finding reinforces arguments by Ahvenniemi et al. (2017) that smart city initiatives must be aligned with environmental objectives to achieve long-term urban resilience. Several studies confirm that the integration of digital infrastructure—such as predictive maintenance systems for street lighting and real-time environmental monitoring—can significantly reduce carbon footprints and optimize energy usage in urban settings (Sudharson et al., 2024; Allam et al., 2019). Moreover, cities that embed geospatial and sensor-based data into planning processes show higher preparedness for climate shocks and flooding risks, contributing directly to SDG 11 (Sustainable Cities and Communities) and SDG 16 (Peace, Justice, and Strong Institutions) (Santos et al., 2021; İkizer, 2022). These global findings underscore the relevance of Malang's efforts and offer comparative validation for its local innovations.

However, the results also highlight persistent challenges that must not be underestimated. The lack of consistent funding for maintenance and upgrades of digital infrastructure is a barrier frequently cited in both domestic and international studies. Setiawan et al. (2021) found that digital infrastructure in Indonesian municipalities often suffers from budget fragmentation and limited post-project sustainability planning, resulting in underutilized or obsolete technologies. Similar concerns were echoed by Judijanto et al. (2023), whose study of Surabaya's Smart City project revealed that long-term success depends on securing multi-year investment plans and aligning them with operational needs. Beyond funding, uneven levels of digital literacy remain a critical challenge, particularly among civil servants and low-income communities. As highlighted in Yohanes (2025), the implementation of smart governance in Pontianak was hampered by infrastructure gaps and a lack of training, which limited the reach and usability of digital services. These findings are consistent with Prasetyo et al. (2022), who argue that capacity-building and human capital development are essential components of successful digital transformation. Without continuous investment in both digital tools and people, smart city initiatives risk becoming fragmented, top-down projects that fail to deliver meaningful improvements in urban governance.

From a theoretical standpoint, this study contributes to the understanding of how mid-sized cities in emerging economies navigate digital transformation. While many studies focus on large metropolitan areas with greater resources and infrastructure (e.g., Jakarta, Singapore), the evidence from Malang shows that smaller cities can also adopt advanced technologies, though their pace and scope of implementation may be shaped by fiscal constraints and institutional readiness. This insight enriches the literature on digital governance by showing that context matters — the same technological solutions can have different outcomes depending on the maturity of governance systems and stakeholder capacity.

The study's novelty lies in its empirical synthesis of qualitative survey data with thematic analysis, producing a nuanced view of both enablers and inhibitors of digital transformation in public asset management. Unlike previous research that focused mainly on technical implementation, this study places equal emphasis on governance, community participation, and sustainability outcomes. This holistic perspective is critical for developing a model of digital transformation that is not only technologically sound but also socially inclusive and environmentally responsible.

Finally, these findings have clear implications for policy and practice. They indicate that digital transformation must be treated as a long-term institutional commitment rather than a series of ad hoc technology projects. The integration of digital literacy training, regulatory reform, and dedicated budget lines for system maintenance will be essential for ensuring that the benefits observed in Malang can be sustained and scaled.

4. Conclusion

This study demonstrates that digital technology has played a transformative role in improving public asset management in Malang City. The adoption of GIS-based mapping, IoT-enabled monitoring, and blockchain-secured records has significantly enhanced the accuracy of asset inventories, streamlined maintenance scheduling, and strengthened bureaucratic accountability. These improvements have led to faster and more evidence-based decision-making, allowing public resources to be allocated more effectively and transparently.

The findings further reveal that digitalization has contributed to greater public trust by increasing transparency and enabling citizens to participate in governance processes through open data platforms and reporting applications. Beyond operational efficiency, the study shows that digital technology supports sustainability objectives by reducing energy consumption, improving climate resilience planning, and aligning urban management with Sustainable Development Goals.

At the same time, the results highlight that digital transformation is not without challenges. Budget constraints, uneven digital literacy among both civil servants and citizens, and regulatory limitations remain significant barriers to full-scale implementation. These constraints underline the need for consistent institutional commitment to maintain and upgrade digital systems, as well as ongoing efforts to build human resource capacity.

Overall, this research contributes to the literature on digital governance by providing empirical evidence from a mid-sized Indonesian city and by demonstrating how digital transformation can simultaneously advance efficiency, transparency, citizen participation, and sustainability. The case of Malang illustrates that, even under resource limitations, local governments can leverage technology to strengthen public asset management and move closer to becoming smart, inclusive, and resilient cities.

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