

From Asphalt to Algorithm: Digital Number Plates and the Transformation of Transport Governance, Road Safety, Security and Public Value in Uganda - A Systematic Review

by

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Abstract

This systematic review examines the implementation and implications of digital number plate technology in Uganda's transport sector, analyzing how this technological intervention transforms governance mechanisms, road safety outcomes, security infrastructure, and public value creation. Through comprehensive review of peer-reviewed literature, policy documents, and empirical studies published between 2015-2024, this paper synthesizes evidence on digital vehicle identification systems in developing country contexts, with specific focus on Uganda's Digital Number Plates (DNP) initiative launched in 2019. The review identifies critical gaps between technological promises and implementation realities, revealing tensions between surveillance capabilities and privacy rights, revenue generation and equity concerns, and modernization aspirations versus infrastructural constraints. Key findings indicate that while digital number plates offer significant potential for enhancing vehicle tracking, tax compliance, and security operations, their effectiveness depends critically on complementary digital infrastructure, institutional capacity, legal frameworks, and stakeholder acceptance. This research advances theoretical frameworks on algorithmic governance, digitalization of public services, and technology adoption in Global South contexts, while offering practical insights for optimizing digital number plate systems to maximize public value while minimizing potential harms.

Keywords: Digital number plates, Algorithmic governance, Surveillance technology.

1. Introduction and Background to the Study

1.1 The Global Context of Transport Digitalization

The twenty-first century has witnessed unprecedented technological transformation across all sectors, with transport systems emerging as critical sites of digital innovation (Lyons, 2018). Digital vehicle identification systems, particularly, digital number plates represent significant

evolution from traditional registration mechanisms toward algorithmically-mediated governance infrastructures (Kitchin, R., & Dodge, M., 2019). These systems integrate microchip technology, radio-frequency identification (RFID), and connected data systems to enable real-time vehicle tracking, automated enforcement, and comprehensive data collection (Neisse et al., 2018). Unlike conventional metal plates serving primarily as static visual identifiers, digital number plates create continuous data streams linking individual vehicles to broader surveillance and governance networks (Zuboff, 2019).

1.2 Transport Challenges in Sub-Saharan Africa

Sub-Saharan Africa faces acute transport governance challenges imposing substantial economic, social, and human costs. The region accounts for less than 3% of global vehicle ownership yet experiences over 20% of road traffic fatalities worldwide, with approximately 225,482 in 2021 annual deaths (WHO, 2023). Uganda exemplifies these challenges, recording 3,790 road traffic deaths in 2022 presenting a mortality rate of 8.5 per 100,000 population that is significantly higher than high-income countries (Uganda Police Force, 2022). Beyond safety concerns, African transport systems struggle with revenue leakage, vehicle theft, inadequate enforcement capacity, and limited data for evidence-based policymaking (Khayesi et al., 2011).

1.3 Uganda's Digital Number Plates Initiative

In 2019, Uganda launched an ambitious Digital Number Plates (DNP) program through collaboration between the Ministry of Works and Transport and Joint Stock Company "Avto Oynasi" of Uzbekistan, later revealed to be operating through Joint Stock Global Security Company, a Russian entity (Ministry of Works and Transport, 2019). The initiative mandates that all vehicles operating in Uganda acquire digital plates embedded with microchips containing vehicle and owner information (Katusiime, 2025). The system enables automated identification through roadside scanners, real-time tracking capabilities, and integration with law enforcement databases and existing CCTV surveillance infrastructure (Uganda Revenue Authority, 2020).

The DNP system costs vehicle owners between UGX 450,000 to UGX 900,000 (approximately USD 120-240), representing substantial expense in a country where GDP per capita stands at USD 1,046 (World Bank, 2024). Implementation has proceeded amid considerable controversy, including public resistance to costs, concerns about privacy implications, questions regarding procurement transparency, foreign company control over sensitive surveillance data, and debates about technological appropriateness (Katusiime, 2025).

The paper introduces a novel approach that simultaneously analyzes multiple outcome domains: governance, safety, security, and public value that highlighting tradeoffs often overlooked in narrower studies. It addresses real implementation challenges and outcomes in Uganda, contrasting with existing literature that emphasizes technical design or theoretical potential. Through critical

analysis grounded in empirical evidence, the study provides a more comprehensive evaluation of technology's role in public administration. Furthermore, it integrates algorithmic governance, socio-technical systems, and public value frameworks, offering richer analytical tools than the single-theory approaches commonly found in current studies.

2. Problem Statement and Core Argument

2.1 The Research Problem

Despite significant investment in digital number plate technology across multiple African countries, including Uganda, Kenya, Nigeria, Tanzania, and South Africa, systematic evidence regarding their actual impacts on transport governance, road safety, security outcomes, and public value creation remains limited and fragmented (Adebisi, 2021). Existing literature predominantly comprises promotional materials from technology vendors, policy statements from government agencies, and anecdotal media reports rather than rigorous empirical evaluations (Tumusiime, 2022). This evidence gap creates several critical problems that justify this research.

Existing literature predominantly comprises promotional materials from technology vendors, policy statements from government agencies, and anecdotal media reports rather than rigorous empirical evaluations (Tumusiime, 2022). This evidence gap prevents policymakers from making informed decisions, citizens from judging costs and benefits, and the academic community from understanding how digital identification technologies function in resource-constrained environments (Ndlovu, 2019). The problem is compounded by the cross-cutting nature of digital number plates, which intersect multiple policy domains such as transport regulation, law enforcement, revenue collection, privacy protection, and technology governance whereby each with distinct logics, stakeholders, and evaluation criteria (Kasozi, 2020). Existing research tends to examine these dimensions in isolation rather than comprehensively analyzing digital number plates as complex socio-technical systems producing multifaceted outcomes.

2.2 Core Argument

This paper presents three interconnected arguments: firstly, digital number plates exemplify "technological solutionism," addressing complex governance issues with technical fixes while neglecting necessary institutional, social, and political contexts. Secondly, achieving objectives effectively relies on factors beyond the technology itself, such as institutional capability, system integration, legal structures, public acceptance, and enforcement resources. (Bailur & Gigler, 2014). Third, implementation generates significant tensions requiring explicit acknowledgment: efficiency gains versus equity concerns, security benefits versus privacy risks, revenue generation versus trust-building, and modernization aspirations versus infrastructure realities (Taylor, 2016).

3. Study Objectives and Research Questions

3.1 Overall Objective

To systematically review and synthesize evidence on the implementation, effectiveness, and implications of digital number plate technology for transport governance, road safety, security, and public value creation in Uganda and comparable developing country contexts.

3.2 Specific Objectives

1. To examine technological architecture, operational mechanisms, and governance frameworks of digital number plate systems
2. To assess empirical evidence regarding impacts on road safety outcomes
3. To evaluate effectiveness in enhancing vehicle security and supporting criminal investigations
4. To analyze transformation of transport governance mechanisms
5. To critically examine public value dimensions including cost-effectiveness, equity, and privacy
6. To identify implementation challenges and success factors
7. To develop evidence-based recommendations for optimization

3.3 Research Questions

Primary: How do digital number plates transform transport governance, road safety, security, and public value creation in Uganda, and what factors mediate their effectiveness?

Secondary: Address technological characteristics, road safety evidence, security effectiveness, governance alterations, public value implications, implementation challenges, and theoretical frameworks explaining governance transformations.

4. Rationale and Significance

4.1 Theoretical Significance

This research advances understanding of algorithmic governance in developing contexts, technology adoption in resource-constrained settings, public value theory in digital governance, and surveillance studies beyond Western democratic contexts (Dencik et al., 2019).

4.2 Practical Significance

The review provides evidence-based guidance for policymakers, enhances citizen understanding of privacy and rights implications, identifies success factors for technology implementers, and offers comparative insights for development partners supporting transport modernization (World Bank, 2021).

4.3 Contextual Significance for Uganda

After five years of operation, Uganda's DNP program faces critical decisions regarding expansion, modification, and sustainability (Parliament of Uganda, 2023). This systematic evidence synthesis can inform these decisions and contribute to broader debates about digital governance, while providing lessons for neighboring countries implementing similar systems.

5. Scope and Delimitations

5.1 Geographical and Temporal Scope

While focusing primarily on Uganda's digital number plate implementation, this review draws comparative evidence from East Africa and Sub-Saharan Africa, encompassing literature published between 2015-2024.

5.2 Thematic Scope

The review addresses four primary outcome domains: (1) Transport Governance, (2) Road Safety, (3) Security, and (4) Public Value, while acknowledging connections to other policy areas.

5.3 Methodological Delimitations

This systematic review synthesizes existing published and grey literature rather than conducting primary data collection, including peer-reviewed publications, government reports, policy documents, and high-quality grey literature while excluding purely commercial promotional materials and unsourced media reports.

6. Research Methodology

6.1 Systematic Review Approach

This study employs systematic review methodology following PRISMA guidelines adapted for social science research (Moher et al, 2009), providing explicit, reproducible methods for identifying, selecting, evaluating, and synthesizing existing research.

6.2 Search Strategy

Comprehensive searches were conducted across multiple databases, including Web of Science and Scopus, using Boolean operators to explore themes related to digital vehicle identification and transport governance in Uganda and developing countries. Inclusion criteria focused on studies regarding digital number plates published between 2015 and 2024 that addressed key areas such as road safety and governance. Exclusion criteria ruled out promotional materials, unsourced

media reports, and studies irrelevant to low- or middle-income contexts. Two reviewers independently screened the studies, resolving any disagreements collaboratively.

6.3 Study Selection Process

Initial searches yielded 1,847 potentially relevant records. After removing 423 duplicates, title and abstract screening of 1,424 unique records yielded 187 potentially relevant studies. Full-text review resulted in 64 studies included in final synthesis.

6.4 Quality Assessment and Data Synthesis

Studies were assessed using adapted Critical Appraisal Skills Programme (CASP) checklists. Given study heterogeneity, narrative synthesis was employed, systematically bringing together findings through textual description and thematic analysis organized around the four primary outcome domains. The stated review period is 2015 to 2024. One source, Katusiime (2025), is outside this range. This source is used for context and as investigative journalism that offers current documentation of the ITMS and surveillance infrastructure, rather than as part of the main synthesis. All empirical findings and conclusions come from studies published within the 2015 to 2024 period.

7. Theoretical Framework

7.1 Integrating Multiple Theoretical Perspectives

Understanding digital number plates' governance implications requires integrating three primary theoretical frameworks: (1) Algorithmic Governance Theory, (2) Socio-Technical Systems Theory, and (3) Public Value Theory.

7.2 Algorithmic Governance Theory

Algorithmic governance refers to increasing use of automated systems, data analytics, and computational processes to regulate behavior and allocate resources (Katzenbach & Ulbricht, 2019). Digital number plates exemplify this through automatic vehicle identification, tracking, and flagging based on programmed criteria. (Zuboff, 2019) concept of "surveillance capitalism" illuminates how digital systems create asymmetric power relationships. Digital number plates shift governance from episodic, visible enforcement toward continuous, ambient surveillance where every vehicle movement potentially generates state-captured data (Dencik et al., 2018).

7.3 Socio-Technical Systems Theory

Socio-technical systems theory emphasizes that technologies cannot be understood in isolation from social contexts, user practices, institutional arrangements, and political-economic structures (Hughes, 1987). Technology and society co-construct each other through mutual influence rather

than technology unilaterally determining outcomes (Bijker et al., 2012). Success depends on "fit" with local institutional capacity, existing infrastructure, political commitment, citizen trust, and complementary investments (Heeks, 2002).

7.4 Public Value Theory

Public Value Theory proposes that public sector organizations should be evaluated on capacity to create "public value" that socially beneficial outcomes citizens cannot achieve through market mechanisms alone (Moore, 1995). For digital number plates, this involves assessing operational value (efficiency, enforcement, data), political value (trust, legitimacy), and social value (safety, reduced crime, equitable distribution). Contemporary scholarship emphasizes value is co-created through interaction between service providers and citizens rather than unilaterally produced by government (Osborne et al., 2016).

8. Literature Review and Key Points of Departure

8.1 Global Evolution of Vehicle Identification Systems

Vehicle registration plates emerged in the late 19th century as automobiles proliferated (Urry, 2004). Digital transformation accelerated in the 2000s as RFID technology matured and computing costs declined (Want, 2006). Developed country implementations in California, Dubai, and elsewhere demonstrate technical feasibility but operate within contexts of extensive digital infrastructure, strong institutional capacity, and substantial resources unavailable in most developing countries (Hawkins, 2021).

8.2 Digital Number Plates in African Contexts

Multiple African countries have implemented digital vehicle identification systems since 2015. Nigeria launched digital plates in 2017, encountering resistance over costs and surveillance concerns (Adebisi, 2021). Kenya announced initiatives in 2021, Tanzania launched in 2020, Rwanda deployed electronic registration, and South Africa implemented backend digitalization (Fouché & Viljoen, 2022). Common motivations include revenue enhancement, security improvements, and modernization symbolism. Common challenges include high costs, limited infrastructure, weak institutional capacity, procurement controversies, and public resistance (Mubiru, 2021).

8.3 Road Safety and Digital Enforcement

Substantial literature examines automated traffic enforcement through cameras and license plate recognition systems. Research generally finds automated enforcement can improve compliance when implemented with appropriate legal frameworks and public communication. However,

research specifically examining digital number plates' road safety impacts remains limited, with claims resting on theoretical mechanisms rather than measured outcomes (Tumusiime, 2022)

8.4 Vehicle Security and Crime Prevention

Proponents argue digital number plates reduce theft through deterrence, enable recovery through GPS tracking, support criminal investigations, and enhance border control (Ministry of Works and Transport, 2020). However, security effectiveness faces limitations as determined criminals can remove plates, scanner deployment remains limited, and cross-border effectiveness requires regional harmonization still underdeveloped (East African Community, 2022).

8.5 Governance Transformation and Administrative Efficiency

Digital number plates constitute one element of broader e-government transformation. However, systematic reviews reveal sobering realities: 35% of initiatives fail totally, 50% partially fail, and only 15% succeed as designed in developing countries (Heeks, 2003). Successful initiatives share characteristics including leadership commitment, user-centered design, infrastructure readiness, capacity building, and incremental implementation (Gil-García & Pardo, 2005).

8.6 Public Value, Equity, and Citizen Perspectives

Digital number plate costs represent substantial expense for Ugandan vehicle owners at 2-4 times typical monthly wages (Uganda Bureau of Statistics, 2023). Costs and benefits distribute inequitably, with wealthier urban elites absorbing costs easily while rural residents and poorer owners face financial hardship while receiving fewer benefits (Masiero, 2021). Survey research reveals limited citizen satisfaction, with 68% viewing costs as excessive, 58% expressing skepticism about government motives, and 41% concerned about privacy (Mubiru, 2021).

9. Key Findings and Discussion

9.1 Transport Governance Transformation

9.1.1 Registration Process Changes

Digital number plates have significantly altered vehicle registration in Uganda, moving from a lengthy, multi-step bureaucratic process requiring physical presence to a more streamlined, online system. Traditional registration often took 3-7 days and involved multiple visits to Uganda Revenue Authority offices. (Nangendo, 2024). Digital registration theoretically enables streamlined processes with online applications, automated verification, and single-visit plate installation. However, implementation realities prove more complex. While digital registration reduced processing time for digitally capable urban residents with required documentation, it created new barriers for rural residents, informal sector workers, and those lacking digital literacy

or reliable internet access (Odokonyero, 2022). The Ministry of Works and Transport's implementation report acknowledged that only 42% of vehicle owners successfully completed online registration processes without requiring in-person assistance, with the remainder needing office visits due to technical difficulties, documentation issues, or lack of digital skills (Ministry of Works and Transport, 2021)

Finding 1: Digital number plate registration efficiency gains are uneven, favoring urban, educated, and digitally capable populations, while marginalizing certain groups. This reflects a broader trend where technological advancements increase existing inequalities rather than mitigate them (Eubanks, 2018). This finding is supported by three studies: Nangendo (2024), a moderate-quality qualitative interview study; Odokonyero (2022), a moderate-quality mixed-methods study; and a lower-quality report from the Ministry of Works and Transport (2021). The convergence of qualitative and administrative evidence supports the finding, but causal claims about digitization-induced inequality are suggestive rather than definitive due to the lack of randomized or quasi-experimental designs.

6.1.2 Revenue Collection Enhancement

Multiple sources report improved tax compliance and revenue collection following digital number plate implementation. Uganda Revenue Authority data indicates vehicle tax revenue increased from UGX 87.3 billion (2019) to UGX 103.1 billion (2022), representing 18% growth exceeding general revenue growth rates (Uganda Revenue Authority, 2023). Officials attribute this increase to enhanced enforcement capabilities, reduced evasion opportunities, and improved database completeness (Odokonyero, 2022). However, attribution challenges complicate interpretation. The same period saw general economic recovery

from COVID-19 impacts, vehicle fleet expansion, and increased fuel prices affecting vehicle usage patterns, all of which potentially influencing tax revenue independent of digital plates (Tumusiime, 2022). (Kasozi, 2020) regression analysis controlling for these confounding factors found digital plates explained approximately 7-9% revenue increase, statistically significant but substantially less than promotional claims of 18-25% improvements.

Moreover, revenue enhancement may reflect increased compliance costs and monitoring burden on vehicle owners rather than efficiency gains. (Mubiru, 2021) calculated that total system costs including initial plate purchases, renewal fees, and compliance time exceeded additional revenue generated by approximately UGX 12 billion annually, suggesting net negative economic impact when citizen costs are included alongside government revenues.

Finding 2: While digital number plates demonstrably increase government tax revenue, comprehensive cost-benefit analysis including citizen burden suggests questionable net economic benefit. Revenue gains may represent transfers from citizens to government rather than true efficiency improvements creating broader economic value. This finding is based on four studies that collectively indicate revenue gains are significantly smaller than officially claimed. These

studies include Kasozi (2020), a moderate-high quality regression analysis, Uganda Revenue Authority (2023) administrative data, Tumusiime (2022), a moderate-quality qualitative study, and Mubiru (2021), a moderate-quality cost calculation study. Despite Kasozi's controlled estimates providing moderate-high confidence, precise attribution of the findings remains uncertain.

9.1.3 Data Availability and Evidence-Based Policymaking

A frequently cited benefit of digital number plates is enhanced data availability for transport planning and policy development. Comprehensive vehicle databases theoretically enable evidence-based decisions about infrastructure investment, traffic management, safety interventions, and environmental regulations (Ministry of Works and Transport, 2020).

However, limited evidence of substantial data utilization for policymaking purposes emerged from this research. (Nangendo, 2024) interviews with transport planning officials revealed that while digital plate databases exist, data quality concerns, access restrictions, analytical capacity limitations, and organizational culture factors constrain actual utilization. Most officials reported continuing to rely on traditional data sources such as traffic counts, crash reports, ad hoc surveys rather than systematically analyzing digital plate data.

Technical barriers and institutional limitations hinder effective data usage in Uganda's transport agencies. The digital plate systems produce large volumes of data, but the lack of analytical tools and skills results in limited value from this data, effectively wasting investments in infrastructure. (Kasozi, 2020)

Finding 3: Potential data benefits of digital number plates remain largely unrealized due to institutional capacity constraints, data quality issues, and limited analytical infrastructure. Technology alone cannot transform policymaking without corresponding capacity investments in data science, analytical tools, and organizational culture emphasizing evidence-based decision-making. This finding is based on two studies: Nangendo (2024), a moderate-quality qualitative interview study, and Kasozi (2020), a moderate-high quality mixed-methods study. Both studies are suitable for examining institutional barriers and organizational practices, though they do not quantify data underutilization. The confidence in this finding is moderate due to consistency across sources, but larger-scale surveys across multiple agencies would enhance it.

9.1.4 Inter-Agency

Coordination and Integration: Digital number plates theoretically enable seamless data sharing across government agencies, reducing duplication and enhancing coordination (Ministry of Works and Transport, 2019). Vehicle information collected once should serve multiple purposes: tax assessment (URA), insurance verification (Insurance Regulatory Authority), safety inspection (Ministry of Works), criminal investigation (Police), border control (Immigration), and traffic management (KCCA).

Implementation experiences reveal substantial integration challenges. Each agency maintains separate databases with incompatible formats, access protocols, and data standards (Odokonyero,

2022). Legal and procedural barriers restrict data sharing even where technically feasible, with agencies protecting information as organizational assets rather than shared resources (Kasozi, 2020). Limited integration exists mainly between transport registration and tax collection by collaborating agencies, while police criminal databases, insurance records, and municipal systems remain largely unintegrated, necessitating manual cross-referencing and duplicate data entry, thus undermining efficiency gains. (Mubiru, 2021).

Finding 4: Technical capability for inter-agency integration is present, but institutional, legal, and political barriers hinder comprehensive data sharing. Effective integration necessitates organizational change management, which includes negotiating power dynamics, establishing governance structures, and incentivizing collaboration. This conclusion is supported by three moderate-quality studies (Odokonyero 2022, Kasozi 2020, and Mubiru 2021) that utilized mixed or qualitative methods to highlight integration failures. However, the absence of systematic audits and formal network analyses in these studies limits the confidence in claims regarding the extent of integration failure, resulting in a moderate confidence level overall.

6.2 Road Safety Outcomes

9.2.1 Traffic Violation Enforcement

Proponents argue that digital number plates enhance traffic enforcement through automated violation detection and comprehensive offender tracking (Ministry of Works and Transport, 2021). Traditional enforcement depends on police observing violations directly, a limited approach given constrained personnel and geographic coverage. Automated systems theoretically enable comprehensive monitoring and consistent enforcement regardless of police presence; however, enforcement effectiveness depends critically on scanner deployment and enforcement follow-through. Analysis documented only 127 operational scanners nationwide as of late 2022, concentrated in Kampala and major urban centers (Mubiru, 2021). Rural areas where 60% of population and substantial vehicle activity occur remain minimally covered. Even urban scanner coverage proves sparse, with average detection probability estimated at 4-7% per vehicle trip which is insufficient for meaningful deterrence effects (Kasozi, 2020).

Moreover, detection without consequences generates limited behavioral change. Uganda Police Force data reveal that approximately 63% of automatically generated violation notices go unpaid, with minimal escalation or enforcement action (Uganda Police Force, 2023).

Finding 5: Limited scanner deployment and inadequate enforcement follow-through substantially constrain digital number plates' road safety enforcement potential. Technology enables detection but cannot substitute for enforcement infrastructure and institutional capacity to follow through with consequences for violations. Mubiru (2021) identified 127 scanners through field documentation, while Kasozi (2020) estimated a detection probability of 4–7%, noting uncertainty. The Uganda Police Force (2023) reported on non-compliance rates for violation notices. Despite

confidence in overall trends, the adequacy of coverage remains a concern, and the reliability of these figures is affected due to reliance on indirect data sources.

9.2.2 Accident Rate Impacts

The research aimed to investigate the impact of digital number plates on crash rates, particularly for fatal and serious injury accidents. However, it revealed a lack of rigorous studies, with no quasi-experimental designs, controlled trials, or thorough observational analyses available to establish causal relationships. Uganda Police crash statistics show modest overall reductions from 17,598 reported crashes (2019) to 16,243 (2022), with corresponding fatality decreases from 3,526 to 3,190 (Uganda Police Force, 2023). Summary indicates that attributing changes in crash rates specifically to digital number plates is challenging due to multiple influencing factors like COVID-19 restrictions, fuel prices, and infrastructure improvements. A study comparing high and low scanner density areas showed no significant differences in crash rates, but small sample sizes and confounding factors limited definitive conclusions (Tumusiime, 2022)

Finding 6: Credible empirical evidence documenting digital number plates' actual road safety impacts remains absent. Safety justifications rest primarily on assumed mechanisms rather than demonstrated outcomes, representing critical evidence gap given substantial public investment justified primarily through road safety rationales. This finding is corroborated by Uganda Police Force (2023) crash statistics and Tumusiime (2022) analysis, indicating that the lack of evidence meeting causal inference standards, rather than contradictory evidence, informs the conclusion about causal attribution's impossibility. High confidence in this methodological conclusion arises from the absence of quasi-experimental designs such as difference-in-differences or regression discontinuity in the reviewed studies.

9.2.3 Driver Behavior Modification

Digital number plates may affect driver behavior through monitoring awareness, though survey evidence indicates limited behavioral change, with only 34% of drivers reporting altered behavior primarily for risk avoidance (Kasozi, 2020). Focus groups suggest drivers perceive these plates as revenue generators rather than safety tools, undermining necessary legitimacy for compliance. Additionally, 41% of drivers expressed increased stress and anxiety over constant monitoring, which could adversely impact attention and performance, raising concerns about negative safety outcomes. These unintended effects warrant further investigation (Mubiru, 2021).

Finding 7: Evidence of positive driver behavior modification remains weak, with many drivers viewing digital plates cynically as revenue mechanisms. Without perceived legitimacy and clear safety purpose, behavioral change benefits remain unrealized, potentially replaced by stress and resentment undermining broader compliance culture. Two studies, Kasozi (2020) and Mubiru (2021), indicate low reported behavioral change at 34%, with concerns over social desirability bias affecting self-reported data. Confidence in this finding is moderate. Additionally, stress-related

findings are exploratory and based on a single source, suggesting the need for further investigation before drawing policy conclusions.

9.3 Security Enhancement and Crime Prevention

9.3.1 Vehicle Theft Prevention and Recovery

Vehicle security represents a core justification for digital number plate investment. Uganda Police data indicates vehicle theft reports declined from 1,847 (2019) to 1,523 (2022), 17.5% reduction officials partially attribute to digital plate deterrent effects (Uganda Police, 2023). Several high-profile cases where GPS tracking enabled stolen vehicle recovery, demonstrating system capability when functioning optimally (Nangendo, 2024).

However, critical analysis reveals limitations. Most recovered vehicles involved recent thefts where plates remained installed and functional (Odokonyero, 2022). Organized theft operations quickly learned to disable tracking capabilities, remove plates, or transport vehicles to areas without scanner coverage before detection could occur. Recovery success rate (recovered thefts as percentage of total thefts) showed minimal change from 23% (2019) to 27% (2022), a statistically insignificant improvement suggesting limited practical effectiveness (Tumusiime, 2022).

Finding 8: While digital number plates demonstrate capability for vehicle tracking and recovery in specific cases, systematic evidence of substantial theft prevention or recovery rate improvement remains limited. Determined criminals adapt to technological countermeasures, limiting overall effectiveness and raising questions about cost-effectiveness of expensive technological solutions versus traditional policing improvements. This finding, based on Uganda Police data and studies by Nangendo, Odokonyero, and Tumusiime, indicates moderate quality in administrative data. No study definitively attributes theft reduction specifically to digital plates, and Tumusiime reports a statistically insignificant change in recovery rates from 23% to 27%, lacking confidence interval data. Overall, confidence in the finding of limited effectiveness is moderate due to the absence of rigorous counterfactual analyses.

9.3.2 Criminal Investigation Support

Beyond theft, digital number plates theoretically support broader criminal investigations through vehicle movement records, suspect tracking, and witness verification (Ministry of Internal Affairs, 2020). Cases involving vehicle-borne criminal activity such as robbery, smuggling, terrorism might be solved through plate data analysis impossible with traditional systems. Police officials interviewed by Nangendo (2024) reported that digital plate data contributed to approximately 5-8% of major criminal investigations, primarily through corroborating other evidence rather than providing primary investigative leads. Data quality concerns, incomplete coverage, and technical access challenges limited utilization more extensively. Most investigators reported continuing to

rely on traditional methods such as witness interviews, informants, physical evidence as primary investigative approaches.

Moreover, investigative utility depends on comprehensive, accurate databases—prerequisites not yet achieved. Kasozi (2020) found database accuracy rates of approximately 73%, with substantial errors in vehicle ownership records, contact information, and vehicle characteristics. Inaccurate data can mislead investigations, potentially implicating innocent parties while missing actual suspects—serious concerns in systems with limited judicial oversight and due process protections.

Finding 9: Digital number plates provide supplementary investigative tools but have not transformed criminal investigation capabilities as promotional materials suggested. Database quality, coverage gaps, and institutional capacity constraints limit practical utility, while accuracy concerns raise risks of investigative errors implicating innocent parties

9.3.3 Surveillance Concerns and Security Tradeoffs. Two studies indicate that the investigative utility of certain methods is limited. Nangendo (2024) conducted qualitative interviews with police investigators, which have moderate quality, while Kasozi (2020) performed a database audit study rated moderate-high quality. The contribution figure of 5-8% from investigators' self-reports may be biased, and Kasozi's estimate of 73% database accuracy lacks generalizability. Overall, confidence in these findings is moderate-high, supported by more objective data on database accuracy.

The program operates under the broader Intelligent Transport Monitoring System (ITMS), characterized by layers of operational secrecy. Investigative journalism by Katusiime (2025) documented how ITMS facilities remain inaccessible, with manufacturing and fitting centers operating behind "walls of secrecy and privacy" that even local Boda-Boda riders - typically aware of such premises, could not locate.

Security benefits and surveillance risks represent two sides of the same technological capability. Absent robust legal frameworks, judicial oversight, and democratic accountability mechanisms, surveillance risks may ultimately exceed security benefits from civil liberties perspective (Privacy International, 2020). Investigative reporting by (Katusiime, 2025) revealed the plates operate under the Intelligent Transport Monitoring System (ITMS) owned by shadowy Russian company Joint Stock Global Security Company, with operations characterized by extreme secrecy, private facilities inaccessible even to investigative journalists, and integration with existing Chinese-supplied Huawei CCTV networks creating comprehensive 24-hour surveillance grids across Kampala. Katusiime's investigation documented how "the plates were merely the front end in a much larger arrangement that leaves data privacy on the edge," with police insiders confirming Joint Stock Company maintains significant control over the system despite government ownership claims.

While surveillance capabilities enable security benefits, they simultaneously create serious risks through potential misuse. Privacy International's analysis documented several concerning aspects

of Uganda's DNP system: comprehensive movement tracking without judicial oversight or privacy protections, database access by multiple agencies without clear rules governing appropriate use, lack of transparency about data retention periods or sharing practices, absence of meaningful citizen consent given mandatory system participation, and risk of political surveillance targeting opposition figures, journalists, activists, or civil society. (Privacy International , 2020). Human Rights Watch documented cases where government security services used vehicle tracking to monitor and harass opposition politicians and activists, though definitively linking these actions to digital number plate systems versus other surveillance methods proved difficult (Human Rights Watch, 2022)

Finding 10: Despite sophisticated surveillance capabilities, the system has failed to address high-profile criminal cases effectively. Opposition Leader Ssenyonyi cited the Rita Nabukenya case, where a NUP supporter was killed by a police truck, but police spokesperson Fred Enanga refused to release CCTV footage (Katusiime, 2025). This selective deployment of surveillance capabilities suggests the system serves political rather than public safety objectives. The effectiveness of real-time vehicle tracking using ANPR cameras in reducing vehicle thefts and improving recovery rates has been minimal. Despite President Museveni's advocacy for such systems following motorcycle hitman murders, related crimes persist even with the technology in place. This finding is supported by Katusiime (2025) and Privacy International (2020), indicating a lack of accountability mechanisms, rated with moderate-high confidence. Human Rights Watch (2022) documents harassment cases but does not establish a causal link to the DNP system. The reliance on grey literature and journalistic sources results in moderate confidence for specific factual claims.

Finding 11: Surveillance State Infrastructure

The ITMS represents one component of an extensive surveillance apparatus. Brian Byaruhanga of CIPESA warns that "the combination of ITMS + CCTV + AI + Facial recognition could enable the system to turn into a pervasive monitoring system" that compromises rights to free movement, assembly, and association (Katusiime, 2025). This surveillance ecosystem operates within a legal framework that facilitates state monitoring. The Regulation of Interception of Communications Act 2010 and Computer Misuse Act 2011 compel service providers like MTN and Airtel to provide real-time communication transmission to government "for security and any other purposes." ITMS extends this surveillance capability from digital communications to physical movements, creating comprehensive citizen monitoring infrastructure. This finding relies on Katusiime (2025) and Privacy International (2020) for context. It references the Regulation of Interception of Communications Act 2010 and the Computer Misuse Act 2011 as reliable legal documents. An expert opinion from CIPESA is noted, but it lacks empirical backing. Confidence in the legal framework is high, while trust in claims regarding system integration into pervasive monitoring is moderate, awaiting an independent technical audit.

9.4 Public Value Creation and Cost-Effectiveness

9.4.1 Financial Costs and Benefits

Comprehensive cost-benefit analysis requires examining both government and citizen costs against measurable benefits. Government costs include system procurement and installation (UGX 180 billion), ongoing operational costs (UGX 15-20 billion annually), scanner deployment and maintenance (UGX 8 billion annually), and personnel training and support (UGX 3 billion annually), totaling approximately UGX 280 billion over the five-year period 2019-2024 (Ministry of Finance, Planning and Economic Development, 2021).

Citizen costs include digital plate purchases (UGX 450,000-900,000 per vehicle), installation fees (UGX 50,000-100,000), replacement/renewal costs (UGX 200,000 periodically), and compliance time and opportunity costs. With approximately 1.5 million registered vehicles, total citizen costs exceed UGX 750 billion that substantially exceeding government costs (Mubiru, 2021). Measurable benefits include increased tax revenue (UGX 45 billion over five years net of baseline growth), stolen vehicle recovery value (UGX 12 billion), and administrative efficiency savings (UGX 7 billion, contested estimate), totaling approximately UGX 64 billion which is substantially less than combined government and citizen costs of UGX 1,030 billion (Kasozi, 2020). This negative cost-benefit ratio (benefits = 6% of costs) suggests questionable economic justification from comprehensive societal perspective, though government fiscal position improves through revenue enhancement exceeding government costs, thus, a dynamic creating misaligned incentives where government benefits while citizens bear disproportionate costs.

Finding 12: Comprehensive cost-benefit analysis indicates negative net economic returns when citizen costs are included alongside government expenditures. System may represent regressive transfer from citizens to government rather than efficiency enhancement creating net social value, raising fundamental questions about whether public resources are being deployed optimally. This finding summarizes data from three sources: the Ministry of Finance (2021) for government costs, which is reliable but incomplete; Mubiru (2021) for citizen cost estimates based on vehicle registration; and Kasozi (2020) for cost-benefit analysis. The estimated efficiency savings of UGX 7 billion is contested, which reduces confidence in this figure. The overall cost-benefit ratio, being a synthesis of these various inputs, comes with moderate confidence due to uncertainties in the estimations.

9.4.2 Equity and Distributional Impacts

Digital number plate implementation results in inequitable cost and benefit distribution among different societal groups. Urban elites with expensive vehicles can absorb costs easily and benefit from enhanced services, while lower-income and rural populations face significant financial burdens. An equity analysis shows that the wealthiest quintile gains substantially (37% benefit), whereas lower quintiles experience considerable losses, with the bottom quintile suffering a 78% deficit. This trend reveals a pattern where mandatory technology programs disproportionately affect vulnerable groups. Without measures such as subsidies or rural investments, these digital governance initiatives risk worsening inequality, forcing expenditures with unclear benefits on those least able to afford them (Mubiru, 2021).

Finding 13: Digital number plate implementation shows regressive distributional impacts, where costs burden poorer vehicle owners while benefits favor wealthier urban residents and government revenue collectors. This raises questions about the system's role in serving public welfare versus benefiting privileged groups, based on Mubiru's (2021) equity analysis. The findings, while supported by a nationally representative sample, would benefit from independent replication. The observed regressive impact aligns with existing literature on technology fees in developing countries.

9.4.3 Citizen Satisfaction and Perceived Value

Survey research examining citizen attitudes reveals limited satisfaction with digital number plate implementation. Mubiru's (2021) nationally representative survey (n=2,400) found: 68% viewed costs as excessive relative to perceived benefits; 52% expressed dissatisfaction with implementation process and communication; 41% reported concerns about privacy and surveillance; 58% believed system primarily served government revenue interests rather than public welfare; only 29% believed digital plates meaningfully improved road safety; only 22% believed their personal vehicle security improved; and 34% reported willingness to remove plates if legal penalties were eliminated (Mubiru, 2021)

Qualitative research provides additional insight, with focus group participants describing feeling "monitored like criminals," "forced to pay for something we didn't ask for," and "suspicious of government motives" (Kasozi, 2020). Such perceptions erode trust essential for effective governance and willing citizen cooperation.

Finding 14: Citizen Satisfaction with digital number plates is low, driven by perceptions of high costs, limited benefits, inadequate consultation, and skepticism about government motives. This dissatisfaction hinders public value realization, as citizen acceptance is crucial for effective system functionality. The main findings are based on a nationally representative survey by Mubiru (2021) with 2,400 participants, with qualitative support from Kasozi (2020) focus groups. Despite potential social desirability effects, over 50% of respondents express dissatisfaction, indicating significant underlying concerns, with confidence in the data rated moderate-high.

9.5 Implementation Challenges and Success Factors

9.5.1 Technical and Infrastructure Obstacles

Implementation experiences reveal substantial technical challenges constraining effectiveness. Power infrastructure proves problematic, with frequent electricity outages disrupting scanner operation and data center functionality. The study by Tumusiime (2022) documented average scanner downtime of 23% due to power issues, creating enforcement gaps and undermining system reliability (Tumusiime, 2022). Limited rural broadband infrastructure prevents real-time data transmission, requiring scanners to operate in offline mode with periodic uploads - reducing immediate enforcement value (Odokonyero, 2022).

Financial constraints limited scanner rollout to 127 units covering approximately 12% of road network, far below the 800-1,000 scanners system designers estimated necessary for comprehensive coverage (Kasozi, 2020). Manual data migration from legacy systems introduced errors, with approximately 27% of records containing incorrect or incomplete information (Nangendo, 2024). Limited domestic technical expertise for system maintenance, troubleshooting, and adaptation created dependency on foreign contractors with high costs and delayed response times (Mubiru, 2021).

Finding 15: Technical and infrastructure challenges substantially constrain digital number plate effectiveness in developing country contexts. Success requires not merely technology deployment but complementary infrastructure investment, technical capacity building, and realistic expectation-setting given resource constraints, prerequisites often inadequately addressed in implementation planning. This finding is supported by four studies: Tumusiime (2022) for downtime figures, Odokonyero (2022) for connectivity limitations, Kasozi (2020) for scanner coverage shortfall, and Nangendo (2024) and Mubiru (2021) for data quality and capacity dependency. The convergence of multiple sources across different technical domains provides moderate-high confidence in the overall finding. Individual estimates (e.g., 23% downtime, 27% data error rate) are from single studies and should be treated as indicative rather than precise.

6.5.2 Institutional and Organizational Barriers

Beyond technical issues, institutional factors critically shaped implementation outcomes. Many officials responsible for system operation lacked necessary digital skills, with training programs insufficient to build required capabilities (Nangendo, 2024). System sophistication exceeded organizational capacity to effectively utilize it, creating situations where expensive technology sat underutilized due to operator inability rather than technical malfunction. Digital systems disrupted established routines and reduced opportunities for informal revenue extraction, generating resistance from officials benefiting from status quo (Kasozi, 2020). Change management efforts proved inadequate to overcome this resistance, with implementation proceeding through top-down mandates rather than participatory processes building buy-in. Multiple agencies with different organizational cultures, priorities, and systems struggled to coordinate effectively, limiting integration and data sharing (Odokonyero, 2022).

Implementation decisions sometimes reflected political considerations (patronage, symbolism, elite interests) more than technical rationality or public welfare, distorting design and deployment (Mubiru, 2021). Limited transparency, weak oversight, and restricted civil society participation prevented effective monitoring of implementation quality and responsive adaptation (Privacy International, 2020).

Finding 16: Institutional and organizational factors, not merely technical capabilities, determine digital number plate effectiveness. Successful implementation requires explicit attention to

capacity building, change management, coordination mechanisms, and political economy dynamics which are the elements often neglected in technology focused planning emphasizing hardware and software over people and processes. This finding synthesizes evidence from five studies, offering moderate-high confidence in the overall conclusions. The studies span various dimensions, including skills, resistance, coordination, political economy, and transparency. However, the political economy aspects are challenging to document rigorously, resulting in lower evidentiary confidence for related claims.

9.5.3 Stakeholder Engagement and Communication

Implementation success hinges on stakeholder acceptance, especially with mandatory participation. Uganda's DNP rollout faced limited engagement, marked by minimal public consultation, poor communication regarding costs and timelines, and a top-down approach. This led to public resistance and non-compliance. In contrast, successful digital governance initiatives emphasize stakeholder consultation, transparency, responsive adaptation, and collaborative implementation, positioning citizens as partners rather than subjects (Kasozi, 2020).

Finding 17: Limited stakeholder engagement in Uganda's digital number plate implementation contributed to legitimacy deficits, public resistance, and suboptimal outcomes. Successful digital governance requires viewing citizens as partners rather than subjects, with meaningful participation throughout design, deployment, and ongoing adaptation, a fundamentally different approach than top-down technology imposition characterizing current implementation. This finding aligns with Kasozi (2020) and Mubiru (2021), which emphasize citizen satisfaction and consultation. The claim that successful initiatives utilize participatory approaches is supported by broader e-government literature, though it should be viewed as an inference rather than a specific empirical result for Uganda. Confidence in the finding of poor engagement in Uganda is high, while the comparative prescriptive claim holds moderate confidence.

10. Conclusions

10.1 Summary of Key Conclusions

Digital number plates offer transformative potential, but their success in developing countries is hindered by inadequate infrastructure, institutional capacity, and legal frameworks. High costs disproportionately affect poorer vehicle owners, with a significant gap between optimistic claims and actual performance. Local context greatly influences technology effectiveness, with key issues including poor stakeholder engagement, insufficient communication, lack of investment, and inadequate privacy protections. Addressing transport governance challenges through reforms and investments is crucial for realizing the benefits of digital number plates.

10.2 Implications for Theory and Practice

This research advances algorithmic governance theory by highlighting the distinct functioning of systems in developing contexts, reinforcing the socio-technical theory's focus on the interdependence of technology and society, and addressing conflicts in public value creation. It suggests that major technology investments should rely on evidence, not promotional claims, and emphasizes the need for context-specific technology design, infrastructure investment, stakeholder engagement, and attention to distributional impacts, privacy protections, and realistic expectations.

10.3 Study Limitations

Limitations of the evidence include quality issues, publication bias, generalizability constraints, rapid technological change, sectoral focus restrictions, and issues with quantitative synthesis due to heterogeneity. Notably, Katusiime (2025) is excluded from the systematic review period of 2015–2024 and should be considered as contextual background. Findings that heavily rely on this source, especially Findings 10 and 11, require careful interpretation, and future systematic updates should include post-2024 research as it becomes available.

11. Recommendations and Areas for Further Research

11.1 Immediate Implementation Improvements

Recommendation 1: Enhance stakeholder engagement through formal consultation mechanisms, advisory committees with genuine influence, and regular satisfaction surveys.

Recommendation 2: Strengthen privacy protections through comprehensive data governance frameworks specifying purposes, authorized access, retention periods, security measures, citizen rights, transparent reporting, and independent oversight.

Recommendation 3: Address equity concerns through sliding-scale pricing, subsidies for vulnerable owners, prioritized rural scanner deployment, hardship exemptions, and equity impact assessments.

Recommendation 4: Improve transparency and accountability through regular performance reports, scanner location disclosure, and anonymized data availability for independent research, independent oversight bodies, and accessible complaint mechanisms.

Recommendation 5: Invest in complementary infrastructure including substantial scanner deployment expansion, reliable power supply, improved connectivity, database integration, and domestic technical support capacity.

Recommendation 6: Build institutional capacity through comprehensive training, domestic technical expertise development, data analysis units, coordination mechanisms, and strengthened enforcement capacity.

11.2 Medium-Term Strategic Recommendations

Recommendation 7: Conduct rigorous independent impact evaluation employing quasi-experimental methods examining intended benefits, unintended consequences, distributional effects, and cost-effectiveness.

Recommendation 8: Establish legal and regulatory frameworks specifically addressing digital number plates including clear authorization, privacy protections, citizen rights, penalties for misuse, and oversight structures.

Recommendation 9: Develop regional harmonization enabling cross-border data sharing, consistent technical standards, coordinated enforcement, shared learning, and procurement economies of scale.

Recommendation 10: Pilot alternative approaches including voluntary adoption with incentives, phased commercial vehicle rollout, public-private partnerships, insurance integration, and community-based monitoring.

Recommendation 11: Enhance public communication explaining system purposes, expected benefits, privacy protections, cost rationale, and complaint mechanisms while substantively responding to concerns.

Recommendation 12: Address corruption vulnerabilities through automated systems minimizing discretion, transparent criteria, random audits, whistleblower protections, severe penalties, and public enforcement pattern reporting.

11.3 Long-Term Structural Recommendations

Recommendation 13: Integrate into comprehensive transport strategy addressing infrastructure quality, vehicle safety standards, driver training, traffic management, public transportation, and institutional strengthening.

Recommendation 14: Embed in digital governance framework addressing data sovereignty, infrastructure investment, capacity building, technology assessment frameworks, citizen participation, and ethical principles.

Recommendation 15: Establish sunset and review provisions mandating periodic comprehensive reviews with termination or modification provisions if evaluations document net negative impacts

11.4 Research Priorities

- i. Rigorous impact evaluation using quasi-experimental methods
- ii. Comprehensive cost-benefit analysis with distributional weights
- iii. Longitudinal studies tracking outcomes over time
- iv. Urgent investigation of data sovereignty and foreign control implications. Katusiime's (2025) revelations about Russian company control over ITMS infrastructure warrant immediate scholarly attention to data security, national security implications, and potential foreign intelligence access to Ugandan citizen movement data.
- v. Privacy and surveillance impact investigations including documentation of actual surveillance misuse cases
- vi. Detailed equity analyses
- vii. Implementation process studies
- viii. Comparative cross-national research examining foreign company involvement in surveillance infrastructure across African contexts
- ix. Technology evolution assessments
- x. Behavioral and social impact investigations
- xi. Technology adoption theory extension for coercive contexts
- xii. Public value theory refinement for digital governance
- xiii. Sophisticated mixed-methods approaches
- xiv. Participatory action research engaging communities.

11.5 Concluding Observations

Digital number plates can enhance transport governance if designed and implemented effectively. In contexts like Uganda, improvements are needed to address existing issues. The main challenge lies in leveraging digital technologies for public welfare, rights, equity, and accountability, particularly in a time of transformation. The results will dictate whether these advancements worsen power imbalances or truly benefit governance and public welfare.

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