Architectural Studies
International Journal
about Architecture

Volume 12, No. 1

UDC 711+658.2
DOI: 10.56318/as/1.2026.67

ISSN: 2411-801X
e-ISSN: 2786-7374

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# Importance-priority matrix analysis for evaluating smart mobility indicators in Egypt's New Administrative Capital

**Abstract.** The rapid development of Greenfield Smart Cities necessitated a strategic approach to prioritising mobility technology to ensure operational efficiency and sustainability. The aim of the study was to develop a prioritisation hierarchy for evaluating smart mobility indicators in the context of urbanism, using an importance-priority matrix analysis for Egypt's New Administrative Capital. By integrating the four symbiotic pillars (infrastructure, digital transformation, service delivery, and governance), the research transitioned from theoretical description to a data-driven execution hierarchy. Methodology employed importance-priority matrix analysis, supported by the Friedman test and Kendall's coefficient of 0.759. Analysis based on thresholds of 4.0985 for importance and 18.00 for priority revealed a bifurcated trajectory for smart mobility management. Results identified 12 Quick Wins in Quadrant 1, led by Electronic Parking Space Reservation (Mean = 4.9574) and Reduction of Traffic Accident Rate (Mean Rank = 5.52), offering high-impact solutions essential for building early public trust. The matrix uncovered a strategic readiness gap in 10 foundational systems in Quadrant 2, designated as Strategic Investment. Indicators such as Real-Time Data-Driven Intelligent Transportation Systems (Mean = 4.8085) and Traffic Data Aggregation faced low execution priority (Mean Ranks > 18.00) due to fragmented institutional mandates and slow planning procedures. 7 indicators in Quadrant 4 related to sustainable behaviour (avoid/shift goals), exemplified by Expansion of Cycling Network Infrastructure (Mean= 2.4468), recorded the lowest importance and priority scores. It was concluded that a successful transition to an integrated mobility ecosystem required a fundamental paradigm shift from a technology-centric model to a governance-first strategy. The developed framework served as a standardised, transferable decision-support tool enabling policymakers to align technological investment with governance readiness. This research contributed to bridging the

**Suggested Citation**:
Okba, E.M., Embaby, M.E., & Saad, B.M. (2026). Importance-priority matrix analysis for evaluating smart mobility indicators in Egypt's New Administrative Capital. *Architectural Studies*, 12(1), 67-79. doi: 10.56318/as/1.2026.67.

Journal homepage: https://arch-studies.com.ua/en
Architectural Studies, 12(1), 67-79
Received: 06.10.2025 Revised: 02.01.2026 Accepted: 24.02.2026 Published: 26.03.2026

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gap between technological deployment and sustainable urban planning through transit-oriented development and smart governance frameworks, ensuring that smart mobility transitions were both resilient and sustainable

**Keywords:** urban modernisation; intelligent transportation systems; statistical ranking; institutional fragmentation; data-driven governance

## INTRODUCTION

The period from 2015 to 2025 had witnessed a radical shift in global urban planning, moving towards integrating technology to achieve city efficiency and resilience. This evolution was particularly evident in rapidly expanding urban cities, where traffic congestion had emerged as a complex structural challenge that exceeded road capacity. D. Beckers & L. Mora (2025) argued that the primary challenge in Smart City Development (SCD) was not technological, but a governance gap rooted in conceptual and process ambiguity. The authors emphasised that SCD must be viewed as a socio-technical transition requiring shared sensemaking among stakeholders to align technological innovation with urban goals. This perspective underscored that fragmented governance and the lack of citywide coordination often led to failure in orchestrating SCD projects. Digital transformation, supported by the Internet of Things (IoT) and Artificial Intelligence (AI), provided a promising path for predictive mobility. M. Islam (2025) demonstrated through a meta-analysis that AI-enabled adaptive control systems can reduce vehicle delays by up to 36%, thereby lowering fuel consumption and greenhouse gas emissions. However, the author emphasised that the efficacy of these algorithms was fundamentally linked to institutional readiness, noting that technical sophistication alone cannot overcome fragmented governance.

J.M. Ngossaha *et al.* (2024) argued that implementing such high-cost infrastructure was often unfeasible for developing nations due to limited capital and fragmented digital utilities. To bridge this gap, researchers proposed a cost-effective architecture for Vehicular Ad-hoc Networks (VANETs) utilising existing motorcycle taxis as mobile roadside units (mRSUs). Scientist's case study in Douala demonstrated that this adaptive approach, which integrated real-time data management and blockchain-based security, had significant potential to improve mobility systems and avoid congestion, achieving a 10% reduction in $CO_2$ emissions and a 15% decrease in traffic waiting times. E.M. Gideon & F. Chepleting (2026) employed a systematic review grounded in the Resource-Based View (RBV) to argue that technical efficacy in smart transportation was strictly contingent upon institutional capacity and cross-sectoral coordination. Notably, the study identified institutional fragility and policy inconsistency as primary inhibitors to mobility transitions in the Global South. Within this context, scientists highlighted a critical gap in Egypt's New Administrative Capital (NAC); while the city adopts the 15-minute city model and high-tech urban design, a disconnect persists between planning and lived environmental efficiency. This gap reinforced the urgent need for a governance-driven approach to prioritise strategic (Intelligent Transportation Systems) ITS interventions, ensuring that digital competencies align with institutional assets to deliver public value rather than remaining mere technical artifacts. Researchers H.B. Faheem *et al.* (2024) confirmed that structural imbalances in the Greater Cairo Metropolitan Area, exacerbated by rapid urban sprawl, require a transition toward advanced technological interventions. The authors argued that, while traditional road expansions often proved inadequate by attracting more traffic, ITS can potentially reduce $CO_2$ emissions by up to 80% and achieve fuel savings of 45% on urban roads. Since transport was a major source of urban emissions, the national transition was being guided by the Avoid-Shift-Improve (ASI) framework to ensure resilience. This direction, as detailed by R.A. Fathy (2025), involved the deployment of ITS across 6,000 km of core highways using international standards like ISO 14813 to ensure interoperability between field sensors and central control centres, effectively mitigating congestion and enhancing road safety.

E. Metwally *et al.* (2023) identified that despite this advanced physical foundation, there was a lack of real-time digital interfaces for traffic congestion information and environmental monitoring. According to S. Tarek & T.I. Nasreldin (2023), Egypt was rapidly transitioning toward an intermediate phase of smart mobility, which demanded the integration of smart solutions into ongoing network upgrades. However, scientists identified a significant discrepancy between expert ratings and actual performance, where high-priority attributes, such as reaching destinations efficiently and on time, remained under-addressed. D.K. Das (2024) argued that transforming urban centres into Smart Sustainable Cities (SSC) required a symbiotic relationship between four cornerstones: infrastructure, service delivery, governance, and digital transformation. M.A. Ali (2021) highlighted the NAC's innovative governance model managed by the Administrative Capital for Urban Development (ACUD). This model employed a holistic Quadruple Helix strategy and a dual-management system via the Commander Control Centre (CCC) and City Operating Centre (COC), supported by a mandatory Smart City Code to ensure operational sustainability. So, the purpose of this study was to establish a prioritisation framework for assessing smart mobility indicators within the urban context, employing an importance-priority matrix analysis for Egypt's New Administrative Capital.

## MATERIALS AND METHODS

This study adopted quantitative descriptive and analytical research design, selected to address the inherent complexity of digital transformation phenomena within new urban contexts. The research process was conducted over an eight-month period from May 2025 to December 2025, comprising three integrated phases: 1) identification and validation of mobility indicators; 2) expert survey administration; 3) statistical prioritisation and gap analysis via IPMA. The study focused on the NAC in Egypt, considered a Greenfield environment and a Living Lab, justifying the development of a standardised framework applicable to similar future smart cities. To ensure a comprehensive and scientifically grounded framework, the 35 mobility indicators were derived through a rigorous three-step selection process. In the first step (Identification), an initial pool of 58 potential indicators was established through a systematic review of ITS literature (Nosratabadi *et al.*, 2020; Islam, 2025). In addition, the guidelines on Sustainable Urban Mobility Plans (SUMPs) (Rupprecht Consult, 2019) and the technical framework for the integrated provision of "Mobility as a Service" (MaaS) (Signor *et al.*, 2019) were examined. A primary pillar for this technical selection was the Egyptian Code for the Foundations and Requirements for Planning, Management, Operation, and Sustainability of Smart Cities, issued by the HBRC (Housing and Building National Research Center, 2023), ensuring alignment with the Egyptian urban context. To ensure global competitiveness, these indicators were cross-referenced and supplemented with the CITY-keys evaluation framework (Bosch *et al.*, 2017), specifically adopting transport-related KPIs focusing on multi-modal accessibility, public transit services quality, and ICT-driven operational efficiency. Furthermore, this identification phase was enriched through a benchmarking analysis of seven leading global and regional smart city cases – Zurich, Singapore, Amsterdam, Boston, Dubai, Riyadh, and Algiers – ensuring the indicators' applicability to the NAC's Greenfield environment by integrating successful operational models ranging from adaptive management to predictive systems. These seven cities were strategically selected to provide a diverse comparative lens for the identification phase. While Amsterdam and Boston offered established frameworks for pilot scalability and predictive maintenance, Singapore, Dubai, and Riyadh provided essential benchmarks for high-level governance and centralised traffic management. Furthermore, the experiences of Zurich and Algiers offered critical lessons on regulatory interoperability and adaptive management in urban environments undergoing digital transformation. By integrating these diverse operational models, ranging from AI-driven adaptation to top-down governance, this benchmarking ensured that the initial pool of indicators was both globally competitive and applicable to the NAC's unique Greenfield environment.

In the second step of the process (Contextual Screening), the synthesised list of 58 indicators was manually screened to exclude components irrelevant to Greenfield contexts or those not applicable to the NAC's current infrastructure phase, resulting in a refined list of 42 indicators. Finally, in the third step (Validation), a panel of three academic experts reviewed this filtered list for content validity and conceptual clarity. This rigorous evaluation led to the final selection of 35 indicators categorised into seven core criteria (A1 to A7). To provide a robust theoretical foundation, these components were structured to reflect the symbiotic relationship among the four pillars of smart sustainable city development: Infrastructure, which provided the bedrock for seamless delivery; Digital Transformation, acting as the catalyst for innovation and efficiency; Service Delivery, the operational output; and Governance, which ensured strategic alignment with the evolving needs of citizens (Das, 2024). This categorisation accounted for the interplay between internal technical requirements and external strategic mandates, aligning with the dual-theoretical approach to adoption dynamics (Fatorachian & Kazemi, 2025). This approach ensured that the selected criteria encompass all smart mobility dimensions required for a Greenfield environment, ranging from institutional readiness (e.g., TMC structure) to user-centric services. To clarify the internal structure, Table 1 demonstrated the conceptual framework and the hierarchical structure of the measurement instrument, illustrating the linkage between the seven main criteria and their respective sub-indicators.

**Table 1.** Conceptual framework and structure of the measurement instrument

| | **Smart mobility management strategic framework** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Criterion** | **A.1 Sustainable transportation** | **A.2 Smart mobility** | **A.3 Passenger services provision** | **A.4 Traffic management centre** | **A.5 Smart parking systems** | **A.6 Intelligent transit management systems** | **A.7 Smart land use planning** |
| **Indicators** | Avoidance of unnecessary trips | Real-time data-driven ITS | Trip Information Provision | Incident Management Systems | Automated smart parking systems | Bus control unit | Smart land use distribution |
| | Shift to more sustainable modes | Advanced traffic management systems | Electronic Payment Systems | Traffic Data Aggregation | Electronic Parking Space Reservation | Automatic Vehicle Location | Planning development axes supporting transport network |
| | Optimising operational efficiency (vehicles & infrastructure) | Advanced traveller information systems | Emergency Services Provision | Environmental Conditions Monitoring | Smart payment/ Ticketing | Transit Depot Management | Smart Planning to Pre-empt Traffic Issues |

*Table 1. Continued*

| | **Smart mobility management strategic framework** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Criterion** | **A.1 Sustainable transportation** | **A.2 Smart mobility** | **A.3 Passenger services provision** | **A.4 Traffic management centre** | **A.5 Smart parking systems** | **A.6 Intelligent transit management systems** | **A.7 Smart land use planning** |
| **Indicators** | Expansion of cycling network infrastructure | Operational systems for commercial vehicles | Security and Safety Measures | Reduction of Greenhouse Gas Emissions | Smart payment/ Ticketing | Bus Scheduling and On-Board Payment System | Smart Planning to Pre-empt Traffic Issues |
| | Ease of access to city services | Advanced public transportation system | Improved Access to Vehicle Sharing Alternatives | Reduction of Traffic Accident Rate | | Driver and Fuel Monitoring System | |
| | | | | | | Traffic Signal Priority Management | |
| | Ease of access to commercial and health services | | | | | Accessibility to Public Transport Modes | |
| | | | | | | Quality Assurance for Public Transport | |

**Source:** developed by the authors

The data collection process followed a structured procedure, where inclusion criteria targeted key stakeholders with relevant professional backgrounds or a direct link to the NAC. This targeted sample included urban planners, architects, government officials, administrative officers, real estate developers, and academics, alongside informed residents as potential users of the NAC network. To maintain data integrity, incomplete submissions and responses exhibiting inconsistent answering patterns were filtered out. The final sample (N = 47) demonstrated professional expertise and diversity, which was critical for the reliability of the IPMA matrix. As detailed in Table 2, approximately 66% of the participants possess over 15 years of work experience, while 23.4% have between 10 to 15 years. Furthermore, the sample exhibited a strategic distribution across sectors; the public sector accounted for 44.7%, reflecting its regulatory role in the NAC, while the private sector and academia represented 34.0% and 21.3%, respectively. Notably, the academic sector representation (21.3%) included residents with academic backgrounds, ensuring that the evaluation of complex ITS indicators integrated both theoretical knowledge and lived operational experience. The participants' roles included technical experts (planners, architects, and developers) at 48.9%, administrative officials at 27.7%, and academics at 12.8%, ensuring the feedback was derived from a well-informed group capable of evaluating complex ITS indicators.

**Table 2.** Socio-demographic and professional profile of the expert sample (N = 47)

| Variable | Category | Frequency (n) | Percentage (%) |
|---|---|---|---|
| Professional role | Technical experts (planners, architects, developers) | 23 | 48.94 |
| | Administrative & officials | 13 | 27.66 |
| | Academics | 6 | 12.77 |
| | Potential users (residents) | 5 | 10.64 |
| Work sector | Public/Government sector | 21 | 44.68 |
| | Private sector | 16 | 34.04 |
| | Academic/Research | 10 | 21.28 |
| Work experience | Less than 10 years | 5 | 10.64 |
| | 10-15 years | 11 | 23.40 |
| | Over 15 years | 31 | 65.96 |

**Source:** developed by the authors

In compliance with the ethical principles of The Declaration of Helsinki (2013), all experts were informed of the research objectives. Their voluntary completion and submission of the survey served as free and informed consent, ensuring the protection of their privacy and the confidentiality of their personal information throughout the data collection and analysis process. The survey was conducted online via Google Forms ensuring accessibility for the diverse expert groups. The questionnaire was designed in dual-question format for each criterion: 1) measuring the importance of 35 specific ITS indicators using a five-point Likert scale (5 = Essential impact, 1 = Weak impact); 2) measuring priority by asking respondents to perform a Forced Ranking of the same indicators (1 = Highest priority) based on technical feasibility and current operational needs. Following data collection, the responses were processed using IBM SPSS Statistics v.28. Descriptive statistics, including means and standard deviations, were calculated to evaluate the importance scores of the 35 ITS indicators, while the Friedman test was employed to determine the statistical significance of priority ranks due to its robustness with non-parametric data derived from forced ranking. Additionally, Kendall's W coefficient was used to quantify the level of consensus among the 47 experts, providing a reliability index for the collective judgment. The IPMA matrix was implemented to visualise the disparity between perceived importance and execution priority, enabling the identification of strategic readiness gaps. The overall arithmetic means of both dimensions served as a neutral cut-off line for the IPMA matrix, forming the horizontal and vertical axes. The calculation of the overall arithmetic means of the importance scores, which formed the horizontal cut-off line:

$$Overall\ Mean\ (Importance) = \frac{\sum_{i=1}^{k} Meani}{N}, \qquad (1)$$

where $Mean_i$ – the calculated mean importance score for the $i$-th indicator; $k$ – the total number of indicators ($k = 35$) included in the analysis.

Similarly, the overall arithmetic means of the priority ranks, which forms the vertical cut-off line:

$$Overall\ Mean\ Rank\ (Priority) = \frac{\sum_{i=1}^{k} Mean\ Ranki}{N}, \qquad (2)$$

where $Mean\ Rank_i$ – the calculated mean rank for the $i$-th indicator, derived from Friedman's test; $k$ – the total number of indicators ($k = 35$) included in the analysis.

By utilising the IPMA matrix, this study identified the gaps between perceived importance and execution priority, allowing for an empirical interpretation of implementation challenges. This approach enabled the identification of systemic non-technical barriers by analysing indicators that recorded high importance but low execution priority, thereby translating the statistical results into a strategic executive roadmap for smart mobility management.

## RESULTS AND DISCUSSION

The results of the IPMA provided an empirical foundation for prioritising smart transportation components in the NAC. By comparing expert assessments of perceived importance with chronological implementation priorities, critical strategic gaps were identified. Specifically, the findings distinguish between immediate operational Quick Wins and foundational components requiring long-term structural investment. The perceived importance of the indicators (Y-axis) was analysed in light of operational implementation priorities (X-axis) to identify strategic gaps through the IPMA matrix. To clarify the application of the IPMA methodology, the calculation for the Electronic Parking Space Reservation (EPS) indicator was provided as an example based on the specific data obtained for the NAC. The position of each indicator in the matrix was determined by its coordinates (X, Y): Importance (Vertical Axis – Y): this was the arithmetic mean of the Likert scores (1-5). For the EPS indicator, the mean importance was calculated as:

$$\mathrm{Mean}_{EPS} = 4.9574. \qquad (3)$$

Since this value was higher than the overall grand mean ($Y = 4.0985$), it was categorised as a high-importance indicator. Priority (Horizontal Axis – X): This was derived from the Mean Rank of the Friedman test (where a lower rank indicates higher priority). For the EPS indicator, the statistical output was:

$$\mathrm{Mean\ Rank}_{EPS} = 9.04. \qquad (4)$$

Since this rank was lower (more prioritised) than the overall grand mean rank ($X = 18.00$), it was categorised as a high-priority indicator. Matrix Positioning: by plotting these coordinates (9.04, 4.9574), the EPS indicator was empirically positioned in Quadrant 1 (Quick Wins). This indicated that the system was both highly valued by experts and feasible for immediate implementation. Table 3 presented the statistical results for the perceived importance of the indicators, including arithmetic means and standard deviations, with the indicators ranked in descending order based on their mean importance scores.

**Table 3.** Descriptive statistics of indicator importance

| Rank (Importance) | Indicator | Criterion | Mean (Y) | Standard deviation (SD) |
|---|---|---|---|---|
| 1 | Electronic Parking Space Reservation | A.5 (SPS) | 4.9574 | 0.20 |
| 2 | Emergency Services Provision | A.3 (PSP) | 4.9362 | 0.32 |
| 3 | Traffic Signal Priority Management | A.6 (ITMS) | 4.9362 | 0.32 |
| 4 | Security and Safety Measures | A.3 (PSP) | 4.9149 | 0.46 |
| 5 | Traffic Data Aggregation | A.4 (TMC) | 4.8511 | 0.55 |
| 6 | Real-Time Data-Driven ITS | A.2 (SM) | 4.8085 | 0.58 |
| 7 | Incident Management Systems | A.4 (TMC) | 4.8085 | 0.54 |
| 8 | Trip Information Provision | A.3 (PSP) | 4.7660 | 0.43 |
| 9 | Quality Assurance for Public Transport | A.6 (ITMS) | 4.7234 | 0.50 |
| 10 | Advanced Traffic Management Systems | A.2 (SM) | 4.5319 | 0.50 |
| 11 | Driver and Fuel Monitoring System | A.6 (ITMS) | 4.5319 | 0.50 |
| 12 | Advanced Public Transportation System | A.2 (SM) | 4.5106 | 0.51 |
| 13 | Advanced Traveller Information Systems | A.2 (SM) | 4.4681 | 0.50 |
| 14 | Reduction of Traffic Accident Rate | A.4 (TMC) | 4.4468 | 0.58 |

*Table 3. Continued*

| Rank (Importance) | Indicator | Criterion | Mean (Y) | Standard deviation (SD) |
|---|---|---|---|---|
| 15 | Automatic Vehicle Location | A.6 (ITMS) | 4.4468 | 0.62 |
| 16 | Ease of Access to Commercial and Health Services | A.1 (ST) | 4.4043 | 0.50 |
| 17 | Optimising Operational Efficiency | A.1 (ST) | 4.3617 | 0.49 |
| 18 | Electronic Payment Systems | A.3 (PSP) | 4.3191 | 0.47 |
| 19 | Automated Smart Parking Systems | A.5 (SPS) | 4.3191 | 0.47 |
| 20 | Bus Control Unit (BCU) | A.6 (ITMS) | 4.3191 | 0.47 |
| 21 | Transit Depot Management | A.6 (ITMS) | 4.3191 | 0.47 |
| 22 | Accessibility to Public Transport Modes | A.6 (ITMS) | 4.1489 | 0.69 |
| 23 | Planning Development Axes Supporting Transport Network | A.7 (SLUP) | 3.5745 | 0.50 |
| 24 | Smart Payment/Ticketing | A.5 (SPS) | 3.5319 | 0.50 |
| 25 | Reduction of Greenhouse Gas (GHG) Emissions | A.4 (TMC) | 3.4894 | 0.51 |
| 26 | Shift to More Sustainable Modes | A.1 (ST) | 3.4681 | 0.50 |
| 27 | Environmental Conditions Monitoring | A.4 (TMC) | 3.4681 | 0.50 |
| 28 | Bus Scheduling and On-Board Payment System | A.6 (ITMS) | 3.4681 | 0.50 |
| 29 | Ease of Access to City Services | A.1 (ST) | 3.4468 | 0.50 |
| 30 | Improved Access to Vehicle Sharing Alternatives | A.3 (PSP) | 3.4255 | 0.50 |
| 31 | Smart Planning to Pre-empt Traffic Issues | A.7 (SLUP) | 3.4255 | 0.50 |
| 32 | Operational Systems for Commercial Vehicles | A.2 (SM) | 3.3191 | 0.47 |
| 33 | Avoidance of Unnecessary Trips | A.1 (ST) | 3.0426 | 0.78 |
| 34 | Smart Land Use Distribution | A.7 (SLUP) | 2.5106 | 0.51 |
| 35 | Expansion of Cycling Network Infrastructure | A.1 (ST) | 2.4468 | 0.50 |
| **Overall mean** | | | 4.0985 | |

**Source:** developed by the authors

So, the descriptive results confirmed a high consensus on the importance of operational solutions for safety and efficiency. The indicator Electronic Parking Space Reservation tops the list with the highest mean of 4.9574, closely followed by Emergency Services Provision and Traffic Signal Priority Management with a joint mean of 4.9362. Conversely, Smart Land Use Distribution (2.5106) and Expansion of Cycling Network Infrastructure (2.4468) recorded the lowest means, indicating their strategic importance was secondary to immediate technical solutions in the experts' priorities. Furthermore, the low Standard Deviation (SD) values for the highest-importance indicators (such as 0.20 for the Electronic Parking Space Reservation indicator) suggested a strong consensus among experts regarding their strategic importance, while higher values (such as 0.78 for the Avoidance of Unnecessary Trips indicator) indicated greater variability in expert assessment. The overall mean for all indicators was 4.0985, which represented the horizontal cut-off line for the IPMA matrix. To analyse the operational implementation priority, the Friedman test was applied to the forced rankings (representing the X-axis of the IPMA matrix) to determine the chronological execution sequence. Table 4 summarised statistical reliability and consensus tests supporting the ranking significance.

**Table 4.** Statistical reliability and consensus tests for indicators ranking

| Statistical Measure | Value |
|---|---|
| Sample size (*N*) | 47 |
| Kendall's *W* | 0.759 |
| Friedman Test Chi-square ($\chi^2$) | 1212.427 |
| Degrees of freedom (*df*) | 34 |
| Asymptotic significance (*p*-value) | <.001 |

**Note:** statistical analysis was performed using the Friedman test to determine ranking significance, and Kendall's coefficient of concordance to measure the strength of expert agreement
**Source:** developed by the authors

As shown in Table 4, the results of the Friedman test indicated a highly statistically significant difference in the prioritisation of the 35 indicators ($\chi^2 = 1212.427$, $df = 34$, $p$-value $< .001$), confirming that the final ranking was non-random. Additionally, Kendall's coefficient of concordance ($W = 0.759$) confirmed a strong and reliable consensus among the experts regarding the priority list. Subsequently, Table 5 presented the mean ranks for the indicators, where a lower mean rank signified a higher priority for implementation.

**Table 5.** Final implementation priorities (Mean Ranks from Friedman's test)

| Rank (Priority) | Indicator | Criterion | Mean Rank (X) |
|---|---|---|---|
| 1 | Reduction of Traffic Accident Rate | A.4 (TMC) | 5.52 |
| 2 | Ease of Access to Commercial and Health Services | A.1 (ST) | 5.82 |
| 3 | Trip Information Provision | A.3 (PSP) | 6.10 |
| 4 | Advanced Public Transportation System | A.2 (SM) | 6.93 |
| 5 | Planning Development Axes Supporting Transport Network | A.7 (SLUP) | 7.04 |
| 6 | Automated Smart Parking Systems | A.5 (SPS) | 7.34 |
| 7 | Traffic Signal Priority Management | A.5 (SPS) | 7.97 |
| 8 | Electronic Parking Space Reservation | A.5 (SPS) | 9.04 |
| 9 | Ease of Access to City Services | A.4 (TMC) | 9.22 |
| 10 | Incident Management Systems | A.6 (ITMS) | 9.22 |
| 11 | Driver and Fuel Monitoring System | A.6 (ITMS) | 10.13 |
| 12 | Smart Land Use Distribution | A.7 (SLUP) | 13.06 |
| 13 | Electronic Payment Systems | A.3 (PSP) | 13.20 |
| 14 | Advanced Traveler Information Systems | A.2 (SM) | 14.32 |
| 15 | Emergency Services Provision | A.3 (PSP) | 14.48 |
| 16 | Smart Planning to Pre-empt Traffic Issues | A.7 (SLUP) | 14.55 |
| 17 | Smart Payment/Ticketing | A.5 (SPS) | 16.34 |
| 18 | Operational Systems for Commercial Vehicles | A.2 (SM) | 17.76 |
| 19 | Advanced Traffic Management Systems | A.2 (SM) | 20.60 |
| 20 | Reduction of Greenhouse Gas (GHG) Emissions | A.4 (TMC) | 20.91 |
| 21 | Traffic Data Aggregation | A.4 (TMC) | 21.28 |
| 22 | Transit Depot Management | A.6 (ITMS) | 21.96 |
| 23 | Expansion of Cycling Network Infrastructure | A.1 (ST) | 22.76 |
| 24 | Optimising Operational Efficiency | A.1 (ST) | 23.49 |
| 25 | Security and Safety Measures | A.3 (PSP) | 23.65 |
| 26 | Automatic Vehicle Location | A.6 (ITMS) | 23.84 |
| 27 | Real-Time Data-Driven ITS | A.2 (SM) | 26.13 |
| 28 | Shift to More Sustainable Modes | A.1 (ST) | 27.39 |
| 29 | Bus Control Unit (BCU) | A.3 (PSP) | 28.10 |
| 30 | Improved Access to Vehicle Sharing Alternatives | A.6 (ITMS) | 28.30 |
| 31 | Environmental Conditions Monitoring | A.4 (TMC) | 28.79 |
| 32 | Avoidance of Unnecessary Trips | A.1 (ST) | 29.54 |
| 33 | Quality Assurance for Public Transport | A.6 (ITMS) | 30.82 |
| 34 | Accessibility to Public Transport Modes | A.6 (ITMS) | 31.56 |
| 35 | Bus Scheduling and On-Board Payment System | A.6 (ITMS) | 32.85 |
| **Overall mean rank** | | | 18.00 |

**Source:** developed by the authors

Results showed that high implementation priorities were focused on immediate operational and safety requirements. The indicator Reduction of Traffic Accident Rate recorded the lowest mean rank (5.52), closely followed by Ease of Access to Commercial and Health Services (5.82), indicating an immediate implementation priority for these components. Conversely, the highest ranked indicators were Accessibility to Public Transport Modes (31.56) and Bus Scheduling and On-Board Payment System (32.85), placing them at the end of the implementation priority list. The overall mean rank was 18.00, which represented the vertical cut-off line in the IPMA matrix. Moving to the cross-analysis and the identification of implementation gaps via the IPMA, the importance scores (means) and priority scores (mean ranks) were integrated into a two-dimensional matrix to determine strategic intervention priorities. The cut-off lines (overall grand means) were established at 4.0985 for importance and 18.00 for priority (mean rank). These values were determined based on the overall arithmetic mean of both dimensions to ensure a balanced and neutral categorisation of the indicators. The value of 4.0985 represented the grand mean of all importance scores, distinguishing between high-importance indicators (Mean ⩾ 4.0985) and low-importance indicators (Mean < 4.0985). Similarly, the priority cut-off line was set at 18.00, representing the overall grand mean of the mean ranks, separating high-priority indicators (Mean Rank ⩽ 18.00) from low-priority indicators (Mean Rank > 18.00). Figure 1 illustrated the distribution of the 35 indicators across the four quadrants.

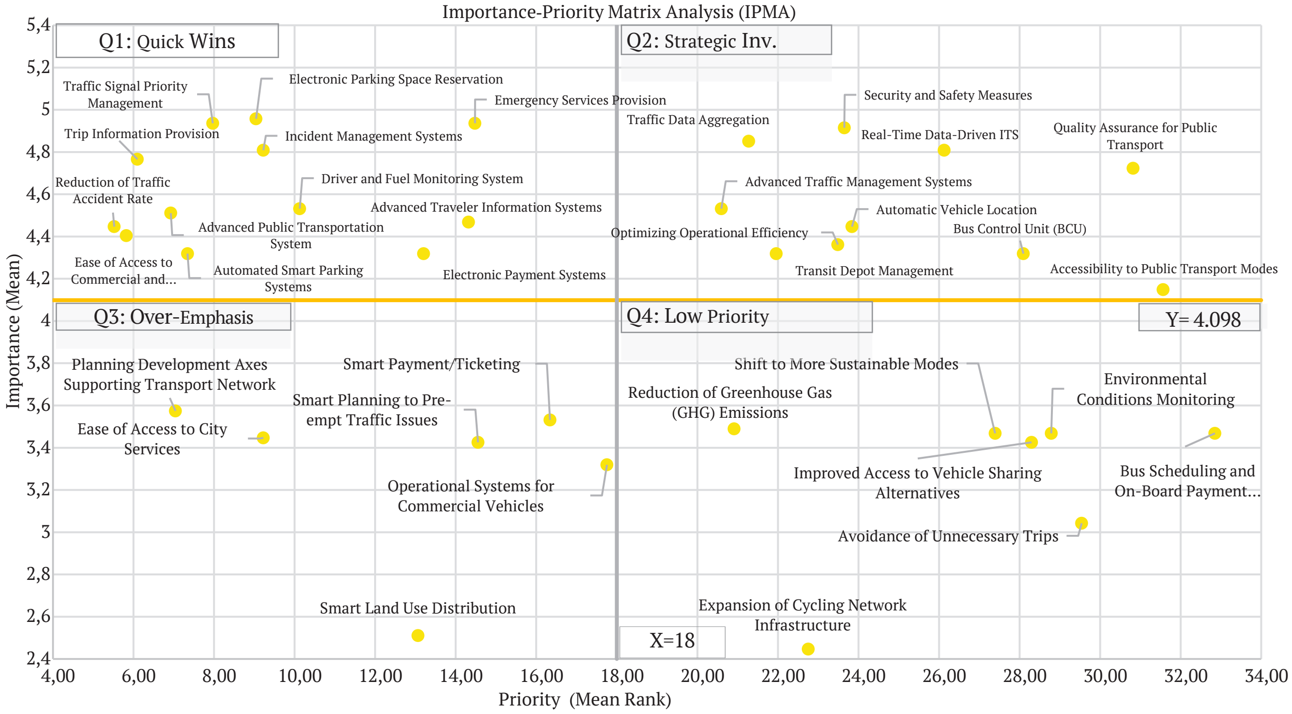

**Figure 1.** Distribution of the 35 smart mobility indicators across the IPMA matrix
**Source:** developed by the authors

The two-dimensional matrix maps the distribution of the 35 indicators across the four quadrants, based on their mean importance (Y-axis) against their priority mean ranks (X-axis), illustrating the strategic gap between perceived importance and execution priority. The matrix revealed that a majority of the indicators were clustered in the high-importance quadrants, highlighting a strong consensus among experts on the necessity of these components. Quadrant 1 (Quick Wins) comprised 12 indicators validated for immediate implementation due to their high importance and high priority, including Electronic Parking Space Reservation, Emergency Services Provision, and Reduction of Traffic Accident Rate, indicating these components offer the highest return on investment in the short term. Conversely, 10 vital structural components were positioned in Quadrant 2 (Strategic Investment), characterising high importance but low execution priority due to structural bottlenecks that require long-term planning, such as Traffic Data Aggregation and Real-Time Data-Driven ITS. Furthermore, Quadrant 3 (Over-Emphasis) features 6 indicators that were rated as low importance but high priority, including Smart Land Use Distribution, suggesting a need for strategy review and potential rerouting of resources. Finally, 7 indicators fall into Quadrant 4 (Low Priority), including Expansion of Cycling Network Infrastructure, indicating it can be deferred to later phases due to lower expert consensus on their immediate importance and priority. A detailed summary of the quadrants, strategic focus, and conditions was provided in Table 6.

**Table 6.** Definition and strategic focus of the IPMA quadrants

| Quadrant | Strategic focus | Description | Conditions/Range | Execution scenario |
|---|---|---|---|---|
| Q1 | Quick Wins (Highest Priority) | High Importance (Y High) + High Priority (X Low Rank) | Y ⩾ 4.098<br>X ⩽ 18.00 | Immediate investment and direct implementation |
| Q2 | Strategic Investment | High Importance (Y High) + Low Priority (X High Rank). Structural Challenges | Y ⩾ 4.098<br>X > 18.00 | Long-term planning and allocation of structural resources |
| Q3 | Over-Emphasis | Low Importance (Y Low) + High Priority (X Low Rank). Strategy Review needed | Y < 4.098<br>X ⩽ 18.00 | Strategy review and rerouting of resources |
| Q4 | Low Priority | Low Importance (Y Low) + Low Priority (X High Rank). Deferral | Y < 4.098<br>X > 18.00 | Postponement of implementation to the next phase |

**Source:** compiled by the authors

Thus, the analysis confirmed that implementation was primarily driven by immediate safety and accessibility needs, as reflected by the high concentration of 12 indicators in Quadrant 1 (Quick Wins). These findings validated a substantial number of highly important and high-priority indicators for immediate execution, offering the highest potential for impact on public satisfaction and system reliability. However, the identified strategic gap in Quadrant 2, where 10 vital structural indicators were consistently ranked as low priority, poses a critical challenge that necessitates systemic interventions. This disparity, encompassing vital indicators characterised by high importance but low execution priority, suggested structural barriers that prevented the immediate execution of highly valued components. The challenges presented by this quadrant will be the main focus of the discussion, as the strategic gap for these essential indicators suggests systemic execution barriers.

So, the analytical results derived from the IPMA framework provided a quantitative mapping of the smart mobility landscape for the NAC. The empirical evidence identified two primary strategic trajectories: first, a robust consensus on Quick Wins (Q1), where 12 indicators, primarily focused on emergency response and parking efficiency, demonstrated high readiness for immediate execution. Second, the identification of a significant Strategic Investment gap (Q2), where 10 foundational indicators, such as Real-Time Data-Driven ITS, exhibited high strategic importance but suffered from low execution priority. Furthermore, the analysis revealed a relatively limited Over-Emphasis (Q3) on 6 indicators, while 7 indicators related to long-term sustainability and urban planning fall into Low Priority (Q4), indicating a secondary focus on non-technical behavioural changes. Practically, these findings demonstrated that despite a high technical appetite for advanced ITS (Overall Mean = 4.0985), the operational path was constrained by structural bottlenecks, necessitating a focus on governance over procurement. These results established that the immediate roadmap for policymakers should not merely focus on technology procurement but must prioritise the institutional and data-governance frameworks required to move Strategic Investment indicators into the Quick Wins category.

Empirical finding of this research aligned with the scholarly perspective of W. van Winden & D. van den Buuse (2017), who emphasised the "low-hanging fruit" approach in early-stage smart city deployment. By analysing pilot projects in Amsterdam, the authors argued that such initiatives were crucial for achieving early public trust. This study confirmed it, as the prioritisation of Q1 indicators demonstrated a clear focus on high-impact, low-complexity solutions. However, a key distinction emerges from their findings: while the surveyed experts perceived these components as high priority Quick Wins, W. van Winden & D. van den Buuse (2017) cautioned that many such pilots fail to scale up once initial funding dries up. This comparison suggested that the NAC's prioritised indicators must be designed with a clear vision for roll-out and replication, as defined in their Amsterdam study, to ensure they do not fall into the pilot trap but instead achieve wider diffusion.

The most critical finding for policy was the pronounced strategic gap identified in Quadrant 2 (Strategic Investment), which encompassed 10 indicators characterised by high importance ($Y \geqslant 4.0985$) but low execution priority ($X > 18.00$ rank). This group included foundational components, such as Real-Time Data-Driven ITS and Traffic Data Aggregation, primarily falling under the Smart Mobility (A.2) and Traffic Management Centre (A.4) criteria. This disparity was further illuminated by the benchmarking of Dubai and Riyadh, where top-down centralised governance and integrated data platforms have proven essential in bridging the gap between infrastructure deployment and operational efficiency. As analysed by A. Badhan *et al.* (2025), Dubai's strategic deployment of AI-powered traffic management systems had demonstrated a 20% reduction in travel time during peak hours. Such models offered a strategic blueprint for the NAC, demonstrating that high-level technological integration must be supported by a robust strategic roadmap and public-private collaboration. These frameworks, alongside the analytical insights of I.R. Hegazy & A. Mahboob (2024), demonstrated that transitioning from Quick Wins to resilient systems required addressing internal organisational barriers. Their evaluation of Riyadh revealed a significant innovation-implementation divide, while the city achieved high performance in public safety through extensive surveillance, it faced persistent challenges in mobility and the digital divide among different social groups. A. Susanty *et al.* (2022) investigated ITS implementation barriers using the Interpretive Structural Modelling (ISM) method. Scientists established that the primary obstacles were not technological capacity, but rather internal organisational barriers related to the timing of procedures for writing plans and divided responsibilities.

The low execution priority of these indicators further reflected the adoption dynamics analysed by H. Fatorachian & H. Kazemi (2025). Researchers utilised institutional theory to demonstrate how external pressures, such as regulatory mandates and industry norms, often constrain the integration of highly valued technologies like AI and Big Data. This explained the disparity in the current findings: while experts recognise the strategic importance of these tools, the lack of coercive regulatory incentives in the Egyptian context stifled their immediate implementation. R. Kitchin & N. Moore-Cherry (2021) demonstrated through their empirical focus on Metropolitan Boston that governance fragmentation created interjurisdictional data incompatibilities and reduced the spatial intelligence necessary for effective ITS. These findings extended this logic to the Egyptian context, where the low priority of data-driven indicators reflected a similar adoption gap caused by path-dependent administrative structures. D. Mitieka *et al.* (2025) applied Total Interpretive Structural Modelling (TISM) to map the hierarchy of barriers in emerging cities. The authors identified legacy paradigms in conventional transport planning and fragmented institutional mandates as the foundational root-cause constraints that reinforced downstream challenges.

Moreover, World Bank (2024) study confirmed that urban transport governance in many developing nations suffered from institutional fragmentation across governance levels, leading to poor policy coordination and inefficient public spending. M. Alamoudi *et al.* (2024) pointed out in their multidimensional analysis of Jeddah that the holistic integration of smart technologies was often hindered by regulatory misalignment and the lack of comprehensive policy reform. The IPMA results reinforced this, indicating that the governance and data policy environment in the NAC were not yet mature enough to support the execution of complex data-driven systems. According to O.L. Lee *et al.* (2019), Singapore's success was built upon a "system of systems" governance framework that integrated the physical infrastructure with organisational capacity and policy regulation. Building on this institutional foundation, G. Hanxiang & L.W. Yie (2025) demonstrated how Singapore's Land Transport Authority (LTA) utilised a centralised analytics engine to achieve predictive coordination and dynamic fleet adjustments.

D. Pojani & D. Stead (2015) argued that in developing cities, technological improvements were often favoured because it was perceived as easier to implement and do not require the deep-seated institutional and behavioural changes necessary for land-use reorganisation. This focus on technology over structure reflected a deviation from the Avoid-Shift-Improve (ASI) framework, a strategic principle championed by S. Lim (2023) of the World Bank in the context of Egypt's green transport master plan. S. Lim (2023) emphasised that, while Egypt had invested heavily in Improvement through massive infrastructure, true transport decarbonisation required a resilient Shift toward public and non-motorised modes. The results indicated that the Improve Dimension (technology and efficiency) was currently prioritised in the NAC over Avoid (reducing trips) and Shift (promoting non-motorised transport), a gap also highlighted by M. Sankar *et al.* (2024) as a common struggle in developing economies seeking seamless mobility. N. Labri & A. Baziz (2022) noted that technical efficacy was strictly contingent upon institutional capacity and cross-sectoral coordination. -Researcher's results, which highlighted a low applicability index due to regulatory gaps, extended this logic to the Egyptian context, where the IPMA results identified a clear "innovation-implementation" divide. Alignment with the Algiers case study suggested that the NAC's digital ecosystem must be deeply ingrained in context-responsive government plans and the standardised framework proposed in this study to ensure long-term regulatory interoperability and effective policy implementation. Operational maturity of Zurich offered a definitive benchmark for the NAC's long-term aspirations. As evidenced by the analysis of M. Menendez & L. Ambühl (2022), Zurich's success is rooted in its "Absolute Priority" policy and technical interoperability across municipal, regional, and national transport agencies, which functioned as a unified entity. The city's transition toward network-adaptive traffic control demonstrated that achieving a "Sustainably Smart" city required shifting from fragmented digital procurement to a unified, data-driven ecosystem.

International standardisation landscape offered a definitive pathway for bridging the current strategic gap. ISO/TR 4447:2022 (2022) provided a robust framework for MaaS, emphasising the necessity of shifting toward unified service consumption via interoperable digital interfaces. Crucially, this framework explicitly defined the roles of data providers, transport operators, and regulators, providing the structural clarity needed to ensure seamless urban mobility. When framing these empirical findings against this ISO benchmark, it became evident that the NAC's evolution from a technologically smart city to a sustainably smart ecosystem required more than technical procurement; it necessitated a transition from siloed deployments to a unified governance model, where these roles were clearly integrated. Adopting the responsibilities defined within the ISO framework would provide the institutional clarity required to transition the identified Quick Wins into the foundational, data-driven systems essential for long-term urban resilience. So, the strategic roadmap for the NAC must transition from technical optimism to institutional consolidation. The main strategic conclusion was that the identified implementation gap in Quadrant 2 was a governance challenge rather than a technological failure, requiring a centralised data exchange infrastructure and regulatory reform. This integrated approach ensured that the NAC's smart mobility vision remained not only operationally viable but strategically resilient against the institutional lags identified in the Egyptian context.

## CONCLUSIONS

This study developed an empirical framework for prioritising ITS within the Greenfield context of Egypt's NAC, transitioning from theoretical modelling to a practical execution hierarchy. The IPMA application moved beyond statistical classification, providing a strategic roadmap, where institutional readiness met technological ambition, based on a high-consensus expert evaluation (Overall Importance Mean = 4.0985, Overall Priority Mean Rank = 18.00). The results established two primary trajectories for smart mobility, the first prioritised operational reliability and public safety as foundational pillars, with 12 indicators identified as Quick Wins (Q1). These were led by Electronic Parking Space Reservation (Mean = 4.9574) and Emergency Services Provision (Mean = 4.9362), these high-impact solutions are essential to build early public trust. The second trajectory revealed a strategic readiness gap in 10 foundational indicators categorised as Strategic Investment (Q2), notably Traffic Data Aggregation and Real-Time Data-Driven ITS. Despite their high strategic value, their implementation was hindered by non-technical barriers and a significant innovation-implementation divide (Mean Rank > 18.00). The proposed framework's reliability is underpinned by a high level of expert consensus (Kendall's $W = 0.759$) and statistically significant priority rankings ($p < .001$), ensuring that the identified roadmap was both robust and representative of institutional reality. Study concluded that a successful transition required a shift toward a governance-first strategy to bridge the identified institutional capacity gap.

Furthermore, the findings identified a sustainability gap in Low Priority areas, where smart land use and cycling infrastructure remained at the periphery of current execution plans, indicating a preference for technical efficiency

(Improve) over behavioural shifts (Avoid/Shift). Integrating transport with TOD was therefore essential for long-term urban growth and resilience. For practitioners and urban planners, the developed IPMA framework served as a validated decision-support tool to align ITS investments with actual institutional capacity, ensuring that technological deployment addressed regional priorities. However, the study faced limitations regarding expert subjective evaluations and the dynamic nature of the NAC's regulatory environment, which may affect the long-term stability of the identified priorities. Future research should focus on developing smart governance frameworks tailored to developing contexts to enhance cross-sectoral coordination and evaluate the financial feasibility of TOD models in aligning technology with sustainable urban planning goals.

## ACKNOWLEDGEMENTS

None.

## FUNDING

None.

## CONFLICT OF INTEREST

None.

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# Аналіз матриці «важливість-пріоритет» для оцінювання індикаторів розумної мобільності в новій адміністративній столиці Єгипту

**Анотація.** Стрімкий розвиток Greenfield Smart Cities зумовив необхідність стратегічного підходу до пріоритезації мобільних технологій з метою забезпечення операційної ефективності та сталого розвитку. Метою дослідження було розроблення ієрархії пріоритетів для оцінювання індикаторів розумної мобільності в контексті урбаністики із застосуванням аналізу матриці «важливість-пріоритет» для нової адміністративної столиці Єгипту. Шляхом інтеграції чотирьох симбіотичних складових (інфраструктура, цифрова трансформація, надання послуг і врядування) дослідження перейшло від теоретичного опису до ієрархії виконання, що базувалася на даних. Методологія передбачала застосування аналізу матриці «важливість-пріоритет», підтриманого тестом Фрідмана та коефіцієнтом конкордації Кендалла (0,759). Аналіз, здійснений на основі порогових значень 4,0985 для важливості та 18,00 для пріоритету, виявив біфуркований траєкторію управління розумною мобільністю. Результати визначили 12 «швидких перемог» (Quadrant 1), серед яких провідними стали електронне резервування паркомісць (Mean = 4,9574) та зниження рівня дорожньо-транспортних пригод (Mean Rank = 5,52), що забезпечували високоефективні рішення, необхідні для формування початкової довіри суспільства. Матриця виявила стратегічний розрив готовності у 10 базових системах (Quadrant 2), визначених як стратегічні інвестиції. Такі індикатори, як інтелектуальні транспортні системи на основі даних у реальному часі (Mean = 4,8085) та агрегування транспортних даних, мали низький пріоритет реалізації (Mean Rank > 18,00) через фрагментованість інституційних повноважень і повільні процедурні процеси планування. Сім індикаторів у Quadrant 4, пов’язаних зі сталими поведінковими практиками (цілі avoid/shift), зокрема розширення мережі велосипедної інфраструктури (Mean = 2,4468), продемонстрували найнижчі показники важливості та пріоритету. Було визначено, що успішний перехід до інтегрованої екосистеми мобільності потребує фундаментального зсуву парадигми від моделі, яка акцентована на технології, до стратегії, орієнтованої на врядування. Розроблена рамка слугувала стандартизованим і відтворюваним інструментом підтримки прийняття рішень, що дало змогу узгодити технологічні інвестиції з рівнем інституційної готовності. Дослідження сприяло подоланню розриву між впровадженням технологій та сталим міським плануванням через підходи транзитно-орієнтованого розвитку та «розумного» врядування, забезпечуючи стійкість та сталий характер трансформацій у сфері розумної мобільності

**Ключові слова:** урбаністична модернізація; інтелектуальні транспортні системи; статистичне ранжування; інституційна фрагментація; управління на основі даних