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AI Agents for Smart City Operations: A Multi Domain Analysis of Global Deployments

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Abstract

Smart cities thrive not only on advanced technologies but on effective governance that strategically harnesses those technologies. This paper examines how AI agents—digital twins, orchestration bots, decision-support systems, and sensor-fusion models—are operationalized to improve city services across mobility, public safety, infrastructure maintenance, permitting, and environmental management. Using a comparative, evidence-based case analysis of global leaders (e.g., Singapore, Seoul, Dubai, Helsinki, Tallinn, Medellín, Buenos Aires), we synthesize technical documentation and official performance reports to (i) describe common architecture patterns such as sensor and data layers, SAOA-style (Sense-Analyze-Orchestrate-Act/Accountability loops), (ii) map data flows and agent capabilities (real-time inference, multi-agent coordination, human-in-the-loop controls), and (iii) quantify operational outcomes. Reported impacts include 15–25% reductions in peak travel times and double-digit increases in transit reliability, faster emergency triage and response, predictive maintenance that cuts service interruptions and inspection cycle time, and measurable savings in fuel, energy, and CO_2 emissions. Cross-domain findings indicate that integration via unified operations platforms and digital twins, coupled with explicit accountability (audit trails, appeal paths, AI registers), is a stronger predictor of sustained performance than any single algorithmic technique. We conclude with implementation guidance for engineering-led city teams: prioritize interoperable data foundations, codify human oversight at decision points, and measure value via service SLAs and cost-to-serve—turning pilots into durable operating capabilities.

Keywords
Smart Cities, AI Agents, Digital Twins, Orchestration and MLOps, SAOA architecture.

1. Introduction

Cities around the world are increasingly deploying artificial intelligence (AI) agents to enhance urban operations and service delivery. These AI-driven systems – from digital twins and smart orchestration bots to decision support agents and sensor fusion AI – act as the "city brain," augmenting human managers in monitoring, analyzing, and optimizing complex urban systems (Abbas et al., 2025). As of the early 2020s, roughly 66% of surveyed cities were investing heavily in AI, a figure expected to rise to 80% within a few years (Deloitte, 2021). The motivation is clear: AI-enabled city operations can yield faster responses, greater efficiency, and better public services. For example, Singapore's AI traffic management cut peak-hour travel times by 20%, raised average speeds from 18 to 21 km/h, and saved an estimated $1 billion annually by optimizing infrastructure use (Nation Thailand, 2025). Such improvements illustrate AI's potential to significantly boost urban performance.

Despite these successes, outcomes vary widely across cities. Implementing smart solutions alone does not guarantee better results – success also hinges on effective governance and system integration Governance Intelligence defines the capacity of city leadership to strategically align technology, data, and human processes toward desired outcomes (Ju and Feng, 2018). In this view, cities with high governance maturity (clear vision, cross-sector coordination, stakeholder engagement) can leverage AI more effectively, translating into measurable gains in mobility, sustainability, and public services (Mikhaylov et al., 2018; Das, 2014). In parallel, reference architectures such as the SAOA stack – Sense, Analyze, Orchestrate, Act – to conceptualize how data-driven decision-making cycles integrate into city operations. In practice, this loop emphasizes key agentic roles: sensing the environment, analyzing data to provide advisory insights, orchestrating coordinated actions across systems, and ensuring accountability for outcomes.) Briefly acknowledging these concepts of governance intelligence and SAOA provide a backdrop for understanding why some AI deployments thrive while others stagnate. Ultimately, smart cities need smart governance to fully realize AI's benefit (Wolniak and Stecuła, 2024).

This paper presents a comprehensive analysis of real-world AI agent deployments supporting smart operations in cities, focusing on multiple operational domains and global case studies. We examine how AI agents are used in urban mobility, public safety, infrastructure maintenance, permitting and city administration, environmental management, and more. Emphasis is placed on technical depth: we describe system architectures (including layered "SAOA-style" designs), data flow schematics, and the specific roles played by AI agents in sensing, decision support, orchestration, and oversight. We compare initiatives from leading smart cities across regions – including Seoul, Tallinn, Dubai, Singapore, Helsinki, Medellín, and Buenos Aires – highlighting recent deployments with verifiable technical references. Key questions guide our study: How have AI agents improved operational performance (e.g. faster service times, higher detection accuracy, lower emissions)? What common architecture patterns and success factors emerge across these cases? How do different domains and city contexts influence AI adoption and outcomes?

By examining cross-domain implementations, the paper sheds light on the operational maturity that AI can enable in city services. We find evidence of significant performance gains: from shorter emergency response times and more efficient transit to smarter inspections and resource savings in waste management. At the same time, we discuss the importance of maintaining human oversight, transparency, and accountability – ensuring that AI augments public sector decision-making in a trustworthy manner.

2. Literature Review

The concept of the "smart city" refers to urban environments that leverage information and communication technologies (ICT), data analytics, and intelligent systems to improve sustainability, efficiency, and livability (Veloso et al., 2024). Early smart city efforts often focused on deploying sensors and networks, for example, installing IoT devices to monitor traffic, air quality, energy use, etc., under the assumption that more data would automatically yield smarter outcomes (Hancke et al, 2013; Bauer et al., 2021). Over time, it became clear that data alone is not enough: the governance and analytical capabilities to transform raw data into actionable decisions are equally vital (Matheus et al.,2020). This realization has driven the rise of AI agents and advanced analytics at the core of city operations.

AI agents in the urban context are software systems (often augmented by machine learning) that can perceive their environment through sensors, reason about complex data, and take actions (directly or via human-in-the-loop) to achieve specific goals in city management. They come in various forms and roles, such as:

- Digital twins: dynamic digital replicas of physical city assets or processes. A city digital twin ingests real-time sensor data to mirror urban conditions and simulate scenarios. For instance, Dublin and Singapore's digital twins help urban planners visualize interdependencies and run "what-if" simulations for disasters or new infrastructure, digital twins enable day-to-day operational support and long-term planning by predicting future states of the city and by the end of 2025, the number of city digital twins worldwide is expected to exceed 500 as adoption accelerates (Deloitte, 2021).

- Orchestration bots / city management platforms: these AI-enabled platforms act as centralized "operating systems" for the city, integrating data from multiple departments and coordinating responses. A notable example is Cascais, Portugal's CitySynergy command center, which integrates 12 municipal domains (transport, safety, utilities, etc.) into a unified operations room (Crompvoets et al., 2022). Through event correlation, visualization dashboards, and even a digital twin, the platform's AI helps predict incidents and coordinate multi-agency responses (Wolf et al., 2022). Many cities are moving towards such unified platforms ("city brains") that break down departmental silos and enable holistic, real-time management (Bibri, 2024).

- Decision support agents: AI systems that analyze data and provide recommendations or forecasts to human decision-makers. These include predictive analytics tools (e.g. crime prediction models, traffic flow predictors) and advisory chatbots for officials. For example, São Paulo's air quality AI analyzes mobile network, weather, traffic, and pollution sensor data to predict pollution levels in advance, allowing authorities to take preventive actions (Costa et al., 2024). Similarly, AI-powered analytics in control centers can pinpoint root causes of issues faster and suggest optimal interventions, such as the best re-routing during a traffic incident (Chowdhury, 2025). Many city governments also use AI chatbots internally for knowledge management or to assist officials in responding to citizen queries quickly (Senadheera et al., 2025).

- Sensor fusion and automation agents: These are AI systems embedded in field operations, using sensor fusion (combining data from cameras, IoT sensors, GPS, etc.) to automate frontline tasks. Examples abound in traffic management (smart signals adjusting lights in real-time), utilities (AI controllers optimizing energy grids or water distribution), and infrastructure maintenance (drones with computer vision scanning for road damage). A representative case is Hangzhou's City Brain in China, which ingests video feeds and other sensor inputs citywide; by optimizing signal timing and emergency routing, it reportedly reduced ambulance response times by up to 50% and dramatically improved traffic flow rankings (Zhang et al., 2019). In New York City, AI using crowdsourced dashcam images now automates crosswalk condition inspections, detecting faded road markings that need repainting without manual surveys (Blyncsy, 2023). Such sensor fusion AI agents effectively extend the eyes and ears of city agencies, enabling proactive maintenance and faster incident detection than traditional methods.

Underpinning many of these applications is a layered architecture. One widely cited conceptual architecture is the four-layer model for smart cities (Samih, 2019): (1) a Perception layer of sensors and devices gathering real-world data, (2) a Network layer transmitting data (via IoT networks, 5G, fiber, etc.), (3) a Data/Analytics layer where data is stored, processed, and analyzed (often on cloud or edge computing platforms), and (4) an Application layer where insights are applied to specific city services (mobility, safety, environment, etc.). This aligns closely with the SAOA agent stack (Sense–Analyze–Orchestrate–Act) mentioned earlier. In the SAOA model, an AI agent senses via the perception layer, analyzes data to generate insights or predictions, orchestrates by coordinating the appropriate response (which might involve dispatching field crews, adjust system parameters, or advise human operators), and then acts on the environment. The cycle repeats continuously, with feedback from outcomes informing the next sensing phase (Regona et al., 2022). It is important to note that recent interpretations of SAOA emphasize human-centric and accountable AI. In many city operations, the "Act" phase is not fully autonomous – AI provides an advisory or decision support role, and human officials execute or approve the final action. Therefore, some experts replace the final "Act" with "Accountability", highlighting the need for auditability, transparency, and human oversight in AI-assisted decisions. For example, a city's AI system may flag 10 buildings as high-risk for safety code violations (analysis) and orchestrate a ranked list for inspections, but a human inspector will verify and be accountable for any enforcement action. Ensuring algorithmic transparency and bias mitigation is a growing concern in these contexts (Kordzadeh and Ghasemaghaei, 2022). Governance frameworks like IGEC (Intelligent Governance of Electronic Cities) have been proposed to measure and enforce such accountability. The IGEC index (e.g. version 2.1 described in recent research) evaluates cities across dimensions like governance, innovation, resilience, quality of life, trust, and partnerships (Quiroga, 2017), essentially gauging how well AI and data are governed in tandem with technical innovation. These considerations tie back to Governance Intelligence: balancing automation with human discretion, and "KPIs before APIs, governance before gadgets," as one city strategist aptly put it (Ju and Feng, 2018). Domain-specific applications include:

Urban Mobility: Transportation has been a flagship domain for AI in cities. Intelligent Transportation Systems (ITS) with AI have shown notable success in reducing congestion and improving transit efficiency. AI-driven analytics, promises to improve traffic flow, reduce congestion, and minimize the carbon footprint (Mohsen, 2024). Empirical cases support this: the SURTRAC system in Pittsburgh (one of the early AI traffic signal systems) reduced travel time by ~25% and idling time by over 40% on pilot corridors through adaptive signal control (Saki and Soori, 2025). Singapore's Smart Mobility 2030 initiative, often cited as a gold standard, integrates AI across traffic lights, toll pricing, and public transit scheduling. By 2022, Singapore reported concrete gains, including average travel time reduction by 25% since implementing AI in traffic management (Pk, 2024). In Europe, cities like Amsterdam and Helsinki have piloted AI for traffic management and parking optimization, yielding improvements in congestion metrics and driver satisfaction (Jørgensen and Ma, 2025). Research efforts in this domain also explore multi-agent coordination (e.g. vehicles and signals communicating) and reinforcement learning for traffic light control. A challenge noted in literature is scaling from pilot intersections to city-wide deployment while handling unpredictable events – which is where integrated platforms (city-wide "brains") and digital twins help test scenarios before live rollout (Gupta, 2025).

Public Safety and Security: AI's role in urban safety ranges from emergency response optimization to crime prevention and disaster management. A well-known system is PredPol (Predictive Policing) which some U.S. and Latin American cities trialed to predict crime hotspots. While early outcomes suggested modest crime rate reductions, later analyses flagged issues of bias and false positives, especially with facial recognition tech (Epps, 2024). More focused deployments have seen success in specific contexts: for instance, Surat, India reported a 27% drop-in crime rate after implementing AI-based surveillance and analytics to assist police (NITI Aayog,2023). In emergency services, AI call triaging has proven transformative. Academic and industry reports highlight that AI voice agents can rapidly classify emergency calls and dispatch help faster than human operators during peak load times (Abi Kanaan, 2025). This is evidenced by Seoul's new 119 AI callbot, which can handle up to 240 simultaneous calls and prioritize urgent cases – an innovation aimed at securing the "golden time" for rescuers when every second counts. From March to July 2025, Seoul's AI emergency call system processed over 11,000 calls that would otherwise have queued, directly connecting ~2,250 critical cases to human dispatchers immediately (Seoul Metropolitan Government, 2025). Literature on disaster management also notes AI's ability to integrate data from various sensors (CCTV, social media, seismic sensors, etc.) to provide early warnings. For example, research in Japan and the U.S. explores AI for earthquake early warning and AI vision to detect crowd stampedes or riots for proactive crowd control. The consensus is that AI augments human responders by filtering signal from noise and directing attention where it's needed most, but does not replace human judgment in life-and-death situations.

Infrastructure Maintenance and Inspections: Maintaining city infrastructure (roads, bridges, buildings, and utilities) is resource-intensive, and AI offers potential efficiencies here. Prior initiatives include computer vision for road condition monitoring – e.g. the city of Chicago and startups like StreetScan used mounted cameras and AI to detect potholes, with studies showing above 90% detection accuracy of significant road defects. Similarly, New York City's Department of Buildings piloted a machine learning model to predict which buildings were most likely to have safety code violations, allowing inspectors to target those (this resulted in a significantly higher hit rate of finding issues per inspection, though exact percentages remain proprietary). In utilities, major water companies have applied AI to sensor data to predict pipe bursts or leaks: for instance, a project in London reduced water main bursts by ~17% by intervening earlier where AI indicated high failure risk (as reported in an IEEE Smart Cities case study, 2021). Digital twins are also used in this domain; Helsinki's 3D city model (discussed later) is not only a planning tool but also helps simulate infrastructure stress (like how adding a new tram line might affect underground pipes or traffic load). Academic literature emphasizes that these AI and digital twin approaches shift city maintenance from reactive to proactive – identifying issues before they become critical failures (Mastercard, 2025). However, challenges include ensuring data quality (sensors must be calibrated and maintained) and integrating AI into existing asset management workflows (many city departments have long-used software or manual systems that staff are accustomed to).

Permitting and City Administration: City governments process large volumes of permits, licenses, and documents – an area ripe for AI-driven streamlining. One celebrated example in literature is Buenos Aires' PROMETEA system, an AI that automates drafting of legal documents, such as routine court rulings or city resolutions (Juárez-Merino, 2025). It achieved this by focusing on repetitive, form-based tasks and was built with strong ethical safeguards: developers followed strict codes, and the system provided full transparency and human oversight at each decision point. This human-centered design ensured that AI supported rather than replaced the judgment of city lawyers, and it has been praised as a model for ethically mindful AI in government (Americas Quarterly, 2025). Another administrative AI tool is chatbots for citizen services. Many cities have launched virtual assistants on websites or messaging apps to handle common inquiries (trash pickup schedules, permit requirements, etc.). For example, Boti, the city of Buenos Aires' WhatsApp chatbot, started in 2019 and has evolved into a city-wide digital assistant handling millions of interactions per month (Mendoza et al., 2025). Boti can not only answer FAQs but also accept service requests (like reporting a broken streetlight) and even process user-submitted photos (such as reading a license plate image to check parking fines). Its success in engaging residents and reducing call center loads has been noted as strengthening trust and efficiency in service delivery. On a broader scale, Estonia's "KrattAI" (Bürokratt) initiative envisions an interoperable network of AI assistants across all government services, enabling citizens to complete any official transaction via a single AI-powered interface (Munoz, 2024). While still being implemented, this concept has influenced global thinking on one-stop digital government. Literature in public administration highlights that these AI deployments free up staff from routine tasks, allowing them to focus on complex cases, and they improve responsiveness (some citizen chatbots achieve 90% answer rates without human intervention). Yet, they also underscore the need for clear accountability: e.g., if an AI chatbot gives incorrect info that leads to a citizen error, the agency must have processes to correct and take responsibility.

Environmental Management and Urban Sustainability: AI is increasingly applied to help cities meet sustainability and resilient goals. Common applications include smart energy grids (using AI to balance supply and demand, integrate renewables), waste management optimization, and pollution monitoring. In Dubai, for instance, the Mohammed bin Rashid Al Maktoum Solar Park uses AI to predict solar output and optimize battery storage, contributing to a more reliable renewable energy supply (Ramachandran et al., 2022).

In waste management, cities like Barcelona and Dubai have deployed "smart bins" with fill-level sensors and AI route optimization for garbage trucks. These systems have cut collection costs and fuel use substantially and preliminary results in Dubai indicate that route optimization alone has achieved a reduction of 19.1% in CO_2 emissions (Hassan et al., 2025). Cascais, Portugal provides a quantified case: by using an AI-enabled smart waste system integrated into their city platform, they expect to eliminate 180,000 km of garbage truck trips and 350 tons of CO_2 emissions annually, saving around €800,000 per year (City of Cascais, 2024). The system not only optimizes routes based on real-time bin data but also schedules pickups at off-peak traffic times, further improving efficiency (Montez, 2024). Another intriguing application is AI for urban forestry and climate: Tokyo's "Plant Doctor" system employs AI vision (YOLOv8 and other models) on drone images to assess tree health and detect disease early (Marques et al., 2024). This proactive tree monitoring helps the city maintain green spaces more effectively, intervening before infestations spread. Meanwhile, Helsinki's Energy and Climate Atlas is built atop the city's digital twin to analyze building energy efficiency and solar potential; city officials can simulate how installing solar panels or retrofitting insulation on specific buildings would impact overall emissions (Torrao, 2025). These examples from literature demonstrate AI's range: from granular optimizations (tweaking a thermostat or rerouting a truck) to strategic analysis (policy decisions on energy and climate). Researchers caution, however, that AI models are only as good as the data and assumptions – thus, integrating domain expertise (like meteorologists for climate models, or sanitation managers for waste models) is crucial to avoid misguidance by algorithms.

Prior research and case studies underline that AI agents are becoming integral to smart city operations across domains. Cities that have documented measurable improvements – reduced commute times, lower crime, cost savings, higher citizen satisfaction – often combine cutting-edge AI technology with strong governance: they set clear objectives, ensure interdepartmental cooperation, engage citizens (to build trust and collect feedback), and maintain oversight mechanisms to track performance. The literature also reveals challenges: interoperability of systems, data privacy and ethics, skills gaps in city staff, and sometimes public skepticism. These factors influence how successfully AI projects move from pilot to scaled deployment (the so-called problem of "pilot purgatory" or "pilot theater" where many projects start but few integrate into everyday operations). In the following sections, we will build on these insights to examine contemporary implementations in leading cities, analyzing how theory meets practice.

3. Methods

This study adopts a comparative case analysis methodology to investigate AI agent deployments in smart city operations. We selected a diverse set of global city cases, focusing on cities that are recognized for innovative use of AI in governance and services and that offer publicly documented results. The primary cases analyzed are Seoul (South Korea), Tallinn (Estonia), Dubai (UAE), Singapore, Helsinki (Finland), Medellín (Colombia), and Buenos Aires (Argentina). These cities span different continents and development contexts – from highly digitalized city-states to emerging smart city pioneers – providing a rich comparative perspective. They were chosen because each has at least one notable AI-driven program in city operations (e.g. Seoul's AI emergency system, Singapore's integrated mobility AI, etc.), and together they cover a broad range of operational domains (mobility, safety, administration, environment, etc.).

The study is primarily qualitative and exploratory, but it leverages quantitative indicators reported by cities. While we did not conduct primary experiments (since these are city implementations in the wild), the methodology is akin to an evaluative case study – assessing implementations against their stated goals. By synthesizing multiple cases, the research aims to derive broader insights into how AI agents can support smart operations, and what performance improvements are realistic. We carried out a multi-step process:

- Literature and Document Review: For each city, we gathered documentation including city government reports, white papers, press releases, academic case studies, and reputable news articles. Priority was given to sources post-2020 to capture the latest developments. For example, we obtained Seoul Metropolitan Government's English-language release on their AI 119 callbot (Seoul Metropolitan Government, 2025), Dubai's smart city initiative summaries (IEREK, 2025), and academic reviews like an MDPI article comparing smart initiatives in

Singapore, Helsinki, Medellín, etc. (Veloso et al., 2024). We also leveraged data from international benchmarking studies, such as Deloitte's City Operations & AI study (Deloitte, 2021), and ESI ThoughtLab surveys) to contextualize individual city findings.

- Data Extraction: From these sources, we extracted details on the architectural design of each AI system (e.g. how sensors, data platforms, and algorithms are arranged), data flows, and explicit performance metrics or outcomes reported. We compiled key metrics like percentage improvements (e.g. reduction in response time, increase in detection accuracy), cost savings, or other KPIs cited for each deployment. These data were organized by domain and city. Where possible, we corroborated performance claims with multiple sources to ensure verifiability.

- Categorization by Domain: To enable cross-case comparison, we categorized each AI deployment into an operational domain (mobility, public safety, infrastructure, governance, environment, etc.). Within each domain, we identified common patterns or approaches – for instance, many mobility-focused agents use real-time sensor fusion and centralized control algorithms, while governance chatbots often use NLP and integrate with legacy databases. This helped us structure the Results section thematically.

- Technical Validation: To enhance the technical depth, we examined whether the sources provided any code-level or architectural framework information. In some cases, we referenced conceptual frameworks (like the SAOA stack or human-in-loop architecture) from the literature to interpret the design of real systems. We also looked for any publicly available architectural diagrams or visuals. When found, we included and cited these schematics to aid understanding. For instance, we include an image of Helsinki's digital twin interface to visualize how data layers are integrated with 3D models for operations. Similarly, we incorporate an image of Seoul's AI emergency call center to illustrate a real deployment of an AI agent in action.

- Analysis and Synthesis: We then performed a cross-case analysis, comparing how different cities approach similar problems with AI. This involved looking at both technical aspects (e.g. cloud-based AI vs. edge computing, rule-based vs. machine learning approaches) and organizational aspects (e.g. was there a special task force or public-private partnership driving the project? How was data governance handled?). We also evaluated the maturity of each deployment: some are still pilots or proof-of-concepts, while others are fully integrated into city workflows. This analysis was used to identify factors linked to successful AI integration (like strong inter-agency collaboration or iterative scaling of pilots) versus factors that impede progress (like lack of skilled personnel or public backlash over privacy).

Data was collected from connected sources and publications as described above. A total of ~30 sources were heavily referenced, including at least 25 academic or industry references post-2020, to ensure up-to-date information. These included peer-reviewed articles, conference papers on city AI platforms, industry research, and official city documents. Notably, we accessed open data from city websites: for example, Helsinki's open platform provided details on their 3D city model and how it's used in operations (City of Helsinki, 2024). Buenos Aires and Dubai's government portals and press releases gave insights into the usage stats of chatbots and AI services. We also used international news outlets for recent developments (such as a March 2025 news article detailing Singapore's AI traffic system results). All sources used are cited inline in the text using the required format and full details are available in the References. The multi-source approach and triangulation improve reliability – if one source claimed a benefit without quantitative detail, we sought additional confirmation or context from other reports.

One limitation in data collection is that not all cities publish detailed evaluations of their AI projects (some may tout successes anecdotally without releasing data). Where information was scant or only promotional, we note it as an observation rather than a verified fact. We intentionally focus on cases with verifiable technical references to align with the research goal of grounding in evidence.

Having described our methods and data, we now proceed to the findings. The Results and Discussion are structured by operational domain for clarity, with each subsection comparing how different cities' AI agents function, and the outcomes achieved. Cross-cutting discussions on architecture and agent roles are interwoven, demonstrating how concepts like SAOA manifest in practice.

4. Results and Discussion

4.1 AI in Urban Mobility: Smarter Traffic and Transit

Efficient urban mobility is a cornerstone of smart city operations, and AI agents have made perhaps the most visible impact here. AI-powered traffic management systems are helping cities optimize flow on congested streets, synchronize public transport with demand, and reduce the environmental footprint of transportation.

Real-Time Traffic Control: Singapore and Dubai exemplify how AI can orchestrate complex traffic networks. Singapore's AI-driven traffic control, part of its Intelligent Transport System (ITS), uses a central "brain" to integrate data from road cameras, GPS probes (taxis, buses), and IoT sensors at intersections. The system (including components like the CRUISE project by A*STAR) continuously analyzes this data to predict congestion and adjusts traffic signal timings on a 40-second cycle across the city (Nation Thailand, 2025). The results have been impressive: peak-hour commute times dropped by 20%, average vehicle speeds rose by ~16%, and annual CO_2 emissions fell by an estimated 500,000 tons thanks to reduced idling. These outcomes confirm predictions in earlier studies that AI can yield double-digit percentage improvements in traffic efficiency (Omnisight, 2025). Furthermore, Singapore avoided or deferred costly road expansion projects (saving an additional $500 million) by relying on AI to wring more capacity out of existing infrastructure.

Dubai, learning from global leaders, launched its own AI-based traffic management under the "Dubai Intelligent Traffic Systems" initiative. Phase I deployed an extensive sensor network and smart signals; by 2022 it was reported that the system improved incident detection by 63% and cut response times by 30% on monitored roads (Khaleej Times, 2023). In 2023, Dubai's Roads and Transport Authority (RTA) began a pilot with a Generative AI vision system (Nota AI) to better identify road hazards (like accidents or stalled vehicles) via CCTV feeds (SmartCitiesWorld, 2023). The AI automatically alerts traffic operators and suggests optimized responses (lane closures, re-routing), which are then implemented through digital signages and traffic apps. Early results indicate more precise and quicker incident management, though full metrics are pending. Dubai is also experimenting with an AI-assisted inspection vehicle for road maintenance – essentially a moving agent that scans road quality and traffic assets, flagging issues in real time (ERTICO Network, 2024). This blurs into infrastructure maintenance, but it directly supports mobility by preventing road faults from causing disruptions.

Public Transport Optimization: AI agents also enhance public transit operations. In Seoul, the integrated transit AI mentioned earlier uses camera feeds in subway stations to gauge passenger volumes, then algorithms adjust train frequency and speeds accordingly (Shin, 2020). As a result, trains arrive more frequently on crowded lines and can even slow down or speed up slightly to ensure even spacing – minimizing the "platooning" of trains and long waits. The system also monitors train component health via IoT sensors (temperature, vibration of critical parts) to predict failures and schedule preventive maintenance, which reduces unexpected breakdowns. Seoul's approach illustrates a comprehensive use of AI: both for operations control (real-time service adjustments) and asset management (maintenance scheduling).

Singapore applies AI to public transport through what could be termed a "demand-responsive transit" agent. Since 2020, an AI system crunches farecard data and other indicators to dynamically allocate buses and trains where demand spikes, reducing overcrowding. As reported, this has increased public transport usage by 25% (since riders find it more reliable) and cut average wait times by over 15% (Nation Thailand, 2025). For example, if a big event lets out crowds or if rain causes more people to take transit, the AI can trigger additional buses on certain routes within minutes. This is complemented by Singapore's ERP 2.0 (Electronic Road Pricing) system – an AI-backed toll adjustment scheme that uses real-time congestion data to set tolls and nudge driver behavior. Higher tolls during emerging jams encourage drivers to shift routes or timing, indirectly balancing traffic loads. It is essentially a pricing agent influencing mobility patterns in real-time.

Autonomous and Connected Vehicles: While fully autonomous cars are still limited in deployment, cities are preparing by using AI in controlled domains. Singapore has autonomous shuttles in a university town and is aiming for AI to handle 25% of all trips by 2030 through autonomous vehicles (AVs). The city's regulators use AI simulations in digital twins to test AV integration scenarios. Dubai similarly has introduced self-driving taxis and an AI-powered Metro optimization that adjusts train speeds to minimize delays (IEREK, 2025). An interesting AI agent in Dubai is the world's first "Robocop" – a patrolling robot assistant with AI that can interact with the public and help enforce rules, including on bike lanes (Digital Watch Observatory, 2024). While somewhat a public relations novelty at this stage (it patrols tourist areas and reports issues to human police), it demonstrates the city's vision of pervasive AI in mobility enforcement and assistance.

Mobility Outcomes: The collective impact of these AI mobility agents is significant. Congestion reduction leads to economic gains (time saved) and environmental benefits (emissions reduction). Singapore's figures have been cited; another often-mentioned case is Hangzhou, China's City Brain, which reportedly moved the city from one of China's top 5 most congested to outside the top 30, dramatically improving average commute times (Zhang et al., 2019). In our cases, by 2025:

- Travel time improvements: significative reduction in peak journey times in cities with mature systems in Singapore and Dubai after Singapore (Nation Thailand, 2025), Medellín also saw smoother traffic with intelligent lights in key corridors, though citywide data is limited (Veloso et al., 2024).

- Public transit reliability: Increased usage and satisfaction. Helsinki, for instance, in its 2022 report, noted that their buses adhere to schedule after implementing AI-based traffic signal priority for late buses and using predictive analytics for fleet management (Helsinki Region Transport, 2023). Singapore's 25% transit increased since 2020, AI accurately predicts travel times, improving reliability and reduced waiting time for buses and trains by over 15% (Nation Thailand, 2025). Medellín's metro and cable car integration with smart payments and apps (not strictly AI, but digital) significantly improved access in marginalized neighborhoods, which the city considers a smart mobility win (Veloso et al., 2024).

- Safety: AI traffic enforcement (cameras detecting red-light running, speeding, etc.) has made roads safer. Dubai credits AI surveillance for reducing traffic fatalities in recent years, alongside other measures (Badhan et al., 2025). In Singapore, automated violation detection and e-fines with ALPR – automatic license plate recognition freed manpower and likely improved compliance (Singhal and Singhal, 2025). Seoul also uses AI in traffic cameras to detect accidents, obstacles or recognize vehicles of interest in real time (Lee et al., 2021).

Despite these positives, challenges remain. Data privacy in traffic monitoring is usually less controversial (since it deals with vehicles, not personal biometric data) but still, cities like Helsinki ensure anonymization of any mobility data shared. Algorithmic fairness issues are minimal in routing decisions, but in enforcement (speed cameras), the uniform application is an improvement over selective human enforcement – yet there must be avenues for contesting automated fines to ensure due process. Integration of AI with legacy traffic control systems is a technical hurdle some cities face; many have had to upgrade infrastructure (sensors, communications) to fully leverage AI. This up-front investment is substantial (Singapore's system was built over decades). However, the ROI in efficiency and capacity often justifies it – one study estimated a smart traffic system can deliver a benefit-cost ratio above 5:1 in large cities (mostly through time savings and emission reductions).

AI agents in mobility demonstrate high operational maturity in cities like Singapore and are moving other cities towards that direction. They embody the SAOA cycle: sensing (cameras, detectors), analysis (predictive models optimizing flows), orchestration (coordinating signals, information to users, and dynamic pricing), and accountability (publishing performance dashboards, allowing public feedback on schemes, etc.). The success stories provide blueprints for other cities – for example, Phuket (Thailand) explicitly modeling its new system on Singapore's, expecting a 30-40% congestion cut (Nation Thailand, 2025).

4.2 AI in Public Safety and Emergency Response

Public safety operations in cities, encompassing emergency call handling, law enforcement, disaster management, and citizen security, are increasingly benefitting from AI agents that augment human capabilities. In our case cities, we see AI being used to speed up emergency responses, enhance situational awareness for police, and even proactively prevent incidents.

Emergency Call Handling (119/911 systems): As introduced earlier, Seoul's AI-powered 119 call center is a pioneering deployment in this domain. The AI agent here is essentially an NLP-driven callbot that can converse with callers to gather essential information (location, nature of emergency) and classify the call's priority level (Seo et al., 2025). During major surges – for example, a natural disaster or a citywide event causing hundreds of calls – the AI ensures no call goes unanswered, whereas previously callers might be on hold or not get through. By handling up to 240 calls in parallel and triaging them, the AI secures faster dispatch for critical cases (heart attacks, fires) that truly need immediate attention. It also detects patterns of concurrent calls (e.g. many people calling about smoke in the same area), which can indicate a large incident like a building fire, and flags this to emergency managers for quicker mass response (Seoul Metropolitan Government, 2025). Human operators remain in the loop – the highest-urgency calls are routed to live dispatchers first, and the AI's notes help them make informed decisions fast. The early results are promising: in its first 4 months, the system handled ~11,434 calls, among which thousands were urgent cases directly expedited. This example highlights an AI agent performing the "sense and analyze" roles (listening to callers and interpreting content) and partially the "act" role (initiating the dispatch process), all under human oversight – a clear case of AI improving speed without replacing human judgment where it counts.

Other cities are following suit. Dubai's police have experimented with AI chatbots for their emergency contact channels (and for non-emergency police inquiries). Additionally, Dubai Police's Command & Control Center has integrated an AI that listens to emergency calls (in Arabic and English) to provide live transcription and key word flagging for operators – this helps in noisy, chaotic calls or if a caller is in distress and hard to understand. Though quantitative data from Dubai on this is scarce, they credit AI with improving their call response times and accuracy of incident logging. In the U.S., some 911 centers are starting to use AI to triage text messages to 911 and route them appropriately, but Seoul's system is one of the first voice call examples globally.

Smart Surveillance and Crime Prevention: AI is also deployed in surveillance systems to enhance public safety. Video analytics using AI can detect unusual activities or recognize faces/objects of interest. For instance, Dubai has a city-wide CCTV network (part of the "Oyoon" program) where AI-based facial recognition is used in high-security areas to automatically identify persons on watchlists – say, known fugitives or missing persons – and alert authorities. They also use AI to analyze feeds for behaviors (loitering in restricted areas, unattended bags, etc.) as a pre-emptive security measure. Dubai claims that these AI smart policing initiatives have contributed to crime reduction and faster case closures, though exact figures are not public. A cited example from Dubai Police is using AI to predict where traffic police should be deployed on a given day for enforcing rules, based on historical violation data and events; they reported a significant drop in traffic offences in areas where this predictive deployment was tried (Lewis et al., 2023).

In Medellín, Colombia, improving safety has been a driver for tech innovation given its history. Medellín uses a system called 12 Eyes (12 Ojos) – an AI-enhanced camera network that reportedly detects armed persons or disturbances in real time in public spaces. Combined with an integrated emergency response app for citizens, this helped reduce emergency response times in some neighborhoods by 40% (as mentioned in a city webinar, 2021). Moreover, Medellín's "Mi Seguridad" program analyzes crime data with machine learning to better allocate police night patrols; early pilots saw a double-digit percentage reduction in robberies in the test districts, showing data-driven deployment works (though socio-economic factors also played a role).

A less high-tech but effective AI application is gunshot detection. Systems like ShotSpotter use acoustic sensors and AI classification to detect gunshots and locate them. While not highlighted in our primary cities, other cities (e.g. New York, Mexico City) use this to respond to shootings faster. It's plausible that some Medellín or Buenos Aires neighborhoods have tested acoustic AI sensors given crime concerns, but we lack specific verification.

Disaster Management and Prediction: AI agents are employed to predict or detect disasters early. Seoul and Singapore both have flood monitoring systems – AI analyzes rainfall data, soil moisture sensors, and storm drain CCTV feeds to predict flash floods. Seoul's system can automatically activate flood gates or pumping stations when thresholds are met, essentially an AI in the loop of urban flood control (Bersabe and Jun, 2025). In earthquake-prone cities (outside our list, e.g. Tokyo, San Francisco), AI models for earthquake early warning and building damage estimation are used – sending automated alerts seconds after a quake to slow trains, stop gas lines, etc. This domain is a bit tangential to daily operations but critical for resilience, and AI's pattern recognition prowess is valuable here.

Impact on Safety Outcomes: It is challenging to attribute changes in crime rates or emergency outcomes purely to AI, since many factors are at play. However, some indicative outcomes from our cases and references include:

- Faster Emergency Response: Seoul's system undeniably cuts the call handling bottleneck – potentially saving minutes in dispatch. The true impact on outcomes (like lives saved) will be assessed over time, but even anecdotal evidence is compelling (e.g. an AI-screened call about a cardiac arrest was forwarded to paramedics 30 seconds faster than usual, which can be lifesaving). Cascais, after integrating AI into its command center, cited improved inter-agency response that helped maintain one of Portugal's fastest EMS times (Deloitte, 2023).

- Crime Reduction and Deterrence: Surat's 27% crime drop post-AI was noted (Tiwari, 2023). Dubai doesn't publicly share crime stats but claims some reductions. Medellín's homicide rate has drastically fallen over the last decade; while that's due to broad socio-political strategies, city tech like CCTV and data analytics have played supporting roles by enabling targeted interventions in violence hotspots (Collazos et al., 2021). In Buenos Aires, an interesting angle is using AI for administrative justice – e.g., Boti chatbot allowing citizens to report minor crimes directly on WhatsApp (Government of the City of Buenos Aires, 2024). This can increase reporting and trust, which indirectly improves safety by better allocation of resources to problem areas.

- Resource Efficiency: AI can reduce false alarms and wasted responses. For example, fire departments often roll trucks for automatic alarms that are false; an AI model analyzing sensor patterns (and even video from alarm locations) could cut false dispatches. Cities like Dubai and Singapore integrate building sensor data and CCTV such that when an alarm triggers, an AI cross-check (e.g. seeing no smoke on camera) might hold back a full dispatch until verified – preventing unnecessary deployments. Quantitatively, Dubai Civil Defence noted a reduction in false alarm responses by about 20% after implementing a smart monitoring platform (which includes some AI logic), per a 2022 annual report.

A key discussion point is ethical use and privacy in public safety AI. Facial recognition and predictive policing are controversial – raising concerns of bias, wrongful identification, and surveillance overreach (Haley, 2025). Buenos Aires provides a fascinating case of a balanced approach: their PROMETEA legal AI was designed with human rights safeguards and transparency, showing how to do AI in government right; yet the city's recent pivot to using ChatGPT in courts (replacing PROMETEA) without clear guardrails was criticized as potentially risky (Americas Quarterly, 2025). This underscores that for public safety and justice, intentional, ethical AI design is paramount (Ahmad, R., Saleem and Hussain, 2025).

In our results, we see that cities obtaining the benefits of AI in safety also implement governance measures: Korea worked with a national telecom standards body to verify the AI callbot's safety and reliability before full deployment (Park et al, 2024). This aligns with the Governance Intelligence concept – marrying tech with governance to ensure sustainable success. AI agents in safety act as force-multipliers for city personnel: eyes that never blink (CCTV analytics), ears that hear distress (emergency callbots), and brains that analyze crime data for insights. But the "heart" (values and judgment) must still come from human governance.

4.3 AI for Infrastructure, Inspections, and City Services

This category covers how AI supports the less glamorous but critical city operations: infrastructure maintenance (roads, bridges, utilities), inspections and permitting, and internal city services/administration. These functions ensure the city runs smoothly and compliantly behind the scenes, and AI is helping to improve efficiency, accuracy, and speed.

Smart Infrastructure Maintenance: Several of our case cities use AI to monitor and maintain physical infrastructure proactively. Dubai's RTA has deployed an AI-powered vehicle for smart road inspections (Moukarzel and Azoury, 2025). This vehicle is equipped with cameras and lidar; its AI software can detect road surface issues (potholes, cracks), signs of wear in traffic signals and signs, and even check the quality of road markings. In trials, this automated inspection covered roads 10 times faster than traditional methods and with high accuracy in detecting defects. The system automatically logs issues into a maintenance ticketing system, prioritizing them by severity. As a result, Dubai expects to reduce manual inspection rounds and fix issues before they grow – improving road quality and safety. Helsinki uses a similar approach for its extensive underground tunnels: AI analysis of sensor data (vibrations, seepage levels) predicts when maintenance is needed, preventing costly tunnel closures by scheduling timely repairs.

Building and Construction Inspections: Ensuring buildings meet codes is a labor-intensive process that AI can streamline. Singapore's Building and Construction Authority (BCA) has experimented with an AI to scan digital building plans for code compliance (an automated plan checker). By using computer vision and rules-based AI, it flags potential violations (like missing fire escapes, insufficient structural support in drawings) for human plan reviewers. This has cut down plan checking time significantly – unofficially. In New York City, a predictive algorithm helps prioritize which buildings to inspect for illegal conversions or unsafe conditions, based on data like complaints, construction permits, and even utility usage anomalies (Ye et al., 2019). Translating to our cases: Buenos Aires could benefit from such AI in their permitting – indeed, Buenos Aires has been digitalizing its construction permit process, and one could foresee integration of AI soon, given their innovative stance with tools like Prometea. Tallinn/Estonia also have digital construction permitting; while their current system is rule-based (eAP application), adding AI to flag errors or suggest improvements is on their roadmap, according to e-Estonia briefs.

Permitting and Licensing Bots: Many city services revolve around processing forms – business licenses, event permits, etc. AI-powered workflow bots can automate steps and even make decisions if criteria are clear. For example, Dubai's smart city office has an initiative called "Paperless Licensing" where an AI verifies that all required documents are present and correct in an application (using OCR and cross-checking databases), which then auto-approves certain low-risk licenses without human involvement. This reduced turnaround for some licenses from days to minutes (Dubai reported 50k instant licenses issued with no human in 2022, likely aided by AI checks). In Buenos Aires, while not fully AI, the government's one-stop portal now uses an AI assistant to guide applicants through permit processes, reducing errors in submissions. Over time, that AI could be entrusted to auto-approve straightforward cases, with humans only reviewing edge cases.

City Chatbots & Virtual Assistants: We touched on Boti in BA – a chatbot that not only informs but also transacts (reporting issues, scheduling appointments, etc.). Boti's AI (based on NLP and integrated with city databases) has substantially reduced the workload on call centers – a cited stat from an IT firm was a 50% operational burden reduction after Boti started handling 2–3 million conversations a month (Nucamp, 2023). Similarly, Tallinn's Bürokratt initiative aims to unify various agency chatbots into one AI assistant that citizens can ask for anything – from filing taxes to checking library books – it's still in development, but pilot versions (like an AI assistant used in the Police and Border Guard Board for info services) have been positive, handling thousands of queries monthly in multiple languages (Government of Estonia, 2024).

Outcome Improvements in Internal Operations: These infrastructure and admin AI agents yield improvements often in the form of efficiency gains and cost savings. Some examples:

- Faster processing and throughput: Prometea's 90 to 1 minute reduction per document means what used to take a team of lawyers a full day can be done in minutes, freeing them for more complex work (Americas Quarterly, 2025). BA's courts reported being able to resolve certain cases faster thanks to this (though now they risk losing that if switching to less specialized AI). For licenses in Dubai, the near-instant issuance for compliant applications means entrepreneurs can start businesses faster – a boost to economic activity (and increased satisfaction).

- Cost reduction: Automated inspections and predictive maintenance save money by preventing failures (e.g. a large water main burst can cost millions, AI that helps avoid one paying for itself). Cascais' integrated platform including smart waste saved €800k/year as noted (City of Cascais, 2024). If we isolate the waste part: fewer truck rolls saved fuel and labor costs. Similarly, predictive maintenance in transit (Seoul's sensors) avoids expensive repairs by catching issues early. Though we don't have a number from Seoul, generally such predictive programs in metros reduce maintenance costs by ~10-15% while also reducing service interruptions.

- Accuracy and compliance: AI's consistency can improve compliance with regulations. For instance, an AI that cross-checks restaurant health permits may catch missing renewals that humans might overlook. This ensures more businesses are properly licensed and following rules. In Helsinki, an AI pilot was used to scan websites of short-term rental listings to identify unregistered rentals for tax/enforcement – something manual staff couldn't easily do at scale. That improved compliance with lodging tax by an estimated few percent, adding to revenue (and fairness) without a huge enforcement team.

One must consider workforce implications: these AI agents take over tasks that were traditionally done by city employees (clerks, inspectors, analysts). Cities are managing this transition by retraining staff for higher-value roles – for example, training building inspectors to use drone footage and AI analysis as part of their job rather than physically visiting every roof. The intent is augmentation, not pure replacement. Indeed, the "human-in-the-loop" model is prevalent: AI flags an issue, human verifies it. AI drafts a document, human signs off. This ensures that the final accountability stays with humans (hence "Accountability" in our agentic roles list). As AI systems prove their accuracy and as trust builds, the balance might shift to more autonomy for AI, but likely always with some oversight mechanism (like random audits of AI decisions, or an appeals process for permits denied by AI).

A forward-looking development is integrating these systems with Governance Intelligence metrics. For instance, IGEC's dimension of "Quality of Life" can be partly measured by these improvements (faster service delivery, less downtime of infrastructure). Model Q maturity would imply a city that not only deploys these AI agents but systematically measures their impact and improves processes accordingly. One could imagine a dashboard for city managers that tracks the "AI assist rate" in operations and outcomes achieved (some cities actually have internal KPIs like "% of permits auto-approved" as a metric).

AI agents in infrastructure and administration might not make headlines like robot police or autonomous cars, but they form the backbone of a truly smart operation. They reduce friction in governance (less paperwork delays, more consistent enforcement) and improve resource allocation (fixing what's broken at the right time). Cities like Dubai and Singapore, which have high-tech public facades, also deeply invest in these back-office AI tools. This comprehensive adoption is what elevates them in smart city rankings – pairing strong leadership and clear strategies with AI-driven innovations to yield notable improvements in services noted for top cities like Singapore, London, and Helsinki (John et al., 2025). As other cities follow, we expect to see more "invisible" AI making municipal services as reliable as electricity: quietly working in the background, only noticeable by the absence of problems that would have occurred without it.

4.4 AI for Environmental Management and Sustainability

Ensuring sustainable urban environments – cleaner air, efficient energy use, reduced waste, climate resilience – is a pressing goal for cities, and AI agents have emerged as powerful tools in this arena. Our case cities demonstrate diverse applications of AI for environmental intelligence and action.

Air Quality Monitoring and Prediction: Cities like São Paulo have implemented AI to tackle air pollution. São Paulo's system uses big data and machine learning to predict air quality 24–48 hours ahead by combining cellular network data (as a proxy for traffic volume) with weather and sensor readings (GSMA, 2022). This allows the city to issue warnings or implement short-term traffic restrictions if a high-pollution event is predicted, and also to strategize long-term (like when to pedestrianize areas). In Helsinki, which generally has good air quality, the focus is on localized monitoring. Helsinki participated in a European AI challenge using neural networks to estimate air quality on streets that have no sensor, by correlating with those that do (considering wind, traffic flows, etc.). AI essentially fills gaps in the sensor network, creating a more granular pollution map to inform citizens and urban planners. This was quite successful, reducing error in estimates and enabling "hyper-local" alerts (like advising schools to keep windows closed on a street when a high NO_2 level is predicted by AI due to an event).

Energy Management and Climate Action: In Singapore, AI assists the energy grid through a system that predicts electricity demand and adjusts in near real-time, coordinating with smart buildings to reduce load during peak periods (demand response). Singapore's building management AIs also optimize HVAC (heating, ventilation, air conditioning) in large facilities, learning occupancy patterns to cut energy waste. A trial in 5 public buildings saved an average 15% on energy consumption using an AI-based HVAC control, which the government is now promoting across its offices. In Dubai's Solar Park, as mentioned, AI is used to forecast solar panel output (accounting for weather and panel conditions) and control storage – ensuring a more stable supply of solar energy (Ramachandran et al., 2022). Additionally, Dubai's smart grids use AI for fault detection and efficient distribution, aiming to maximize renewable integration. Net effect: improved renewable utilization, fewer outages, and progress towards Dubai's Net Zero 2050 plan (IEREK, 2025).

Helsinki's climate atlas (built on the digital twin) uses AI simulations to evaluate interventions. For instance, if the city plants X number of trees in certain areas, an AI model estimates the urban cooling effect and air quality improvement. Or if a particular district switches from oil heating to heat pumps, the model projects the CO_2 reduction. This helps prioritize actions in Helsinki's Carbon Neutral 2030 initiative. Notably, Helsinki has opened these tools to the public in a visual way, promoting transparency and engagement in climate strategy (City of Helsinki, 2024).

Water and Wastewater Management: Smart water systems use AI to detect leaks (by analyzing pressure sensor data and water flow patterns). Medellín has a project using AI for its water utility to quickly pinpoint pipe leaks in the extensive network, which is crucial given the city's mountainous terrain (leaks can cause landslides). It reportedly improved detection time by 20% and cut water loss, supporting Medellín's sustainability goals (Veloso et al., 2024). In Tallinn, the water company piloted an AI for predictive pump maintenance and optimizing pumping schedules to save energy; early results showed ~10% energy savings in wastewater treatment, aligning with their green goals.

Waste Management Optimization: We discussed Cascais' success with AI in waste routing (City of Cascais, 2024). Similarly, Dubai installed smart recycling bins with AI sensors that auto-sort recyclables and signal for collection when full (IEREK, 2025). The AI in those bins recognizes paper, metal, etc., and guides items to compartments – increasing recycling rates by reducing contamination. Buenos Aires has started using AI in its waste management too: an Argentinian startup partnered with the city to use AI vision on garbage trucks to identify bins on fire or illegal dumping spots (through cameras as trucks do rounds). This helps the city respond faster to such issues, preventing larger environmental hazards.

Urban Ecology and Green Spaces: Another innovative use of AI is in urban forestry, as with Tokyo's tree health monitoring (Marques et al., 2024). While we don't have evidence of our main cities doing exactly that, Helsinki did experiments with AI and drones to count its urban tree canopy and assess growth, feeding data into environmental models. Singapore uses an AI tool to analyze satellite imagery and LiDAR scans of greenery to measure its "green cover" and identify where to plant more trees for maximum heat mitigation – part of its Smart Nation sensor platform.

Outcomes and Benefits: The environmental AI agents primarily contribute to preventive action, efficiency, and informed policymaking. Key benefits include:

- Emissions Reduction: AI contributions here are indirect but valuable. Singapore's AI traffic and building systems together have a marked emissions cut (traffic AI: 500k ton CO_2/year less(Nation Thailand, 2025), building AIs perhaps another chunk). Cascais noted 30% reduction in water consumption and significant energy savings (20-30%) after their AI-driven operations revamp (City of Cascais, 2024), some of that likely due to eliminating wasteful practices via data-driven optimization. These are major sustainability wins.

- Resource Efficiency and Cost Savings: Reducing water leaks saves precious water (especially important as climate change stresses supplies) and saves the energy that would have treated wasted water. Optimizing electricity use in buildings and pumps lowers city utility bills. For instance, Dubai's DEWA (water & electricity authority) credits smart systems (including AI) for avoiding hundreds of millions of AED in infrastructure expansion by making current systems more efficient.

- Resilience and Adaptation: Predictive models for floods, pollution, etc., enable cities to adapt faster. If an AI can give a few hours' notice of potential flash floods, cities can deploy pumps and warn citizens, reducing damage. As climate risks grow, these early AI warning agents will be increasingly life-saving. Medellín, for example, is developing an AI-based landslide prediction using rainfall, soil sensors, and historical data to evacuate areas in advance – essential for a city built on steep slopes (this is in pilot stage under their disaster management unit, with support from academic partners).

- Citizen Engagement and Awareness: AI-driven insights are often shared via dashboards or apps, raising public awareness. Helsinki's open data on energy and air quality, or BA's public-facing maps of real-time environmental data (they have an open portal that includes AI-estimated noise levels and air quality, updated hourly). When citizens see data and predictions, it both educates and allows them to make choices (e.g., choose to bike on a route with cleaner air as shown by the map).

One could argue that these environmental AI agents reflect the "Advisory" role strongly: they advise city officials (and even the public) on what is happening or will happen environment-wise. The "Orchestration" comes in when these AI systems directly control equipment (like floodgates or HVAC systems) or trigger multi-department responses (air pollution episode causing health advisories and traffic rerouting). Accountability in these systems means ensuring the AI models are accurate and not biased (less of a social bias issue, more of a technical accuracy issue). Cities handle this by continuous model validation – e.g., comparing AI predictions to actual outcomes and retraining as needed, or having expert oversight (a meteorologist might oversee the pollution model's outputs). This feedback loop is akin to how Governance Intelligence emphasizes learning and adaptation in governance processes (Ju and Feng, 2018).

AI agents are proving indispensable for cities striving to meet sustainability targets. They provide the intelligence to not only react efficiently but to plan proactively – which is critical given the ambitious climate and development goals many cities have set for the next decade. As urbanist researchers Veloso et al. (2024) conclude, most smart city initiatives currently emphasize governance and environment domains, yet there's still a need for comprehensive assessment of their social benefits. Our analysis shows that when properly implemented, AI in environmental operations does translate to concrete benefits like cleaner air, reduced waste, and better resource management, which in turn improve citizens' quality of life. Moving forward, cities will likely integrate these AI systems into a unified sustainability dashboard, tracking how each AI-driven intervention contributes to indicators, much as Cascais did by signing "citizen service level agreements" for outcomes like energy and water savings (City of Cascais, 2024).

4.5 Cross-Domain Synthesis: Architecture Patterns and Agentic Roles

Having examined each domain, we can distill some common architectural patterns and roles that AI agents play across smart city operations. These cross-cutting themes tie back to the SAOA (Sense–Analyze–Orchestrate–Act/Accountability) framework and illustrate how a coherent architecture can underpin diverse applications.

1. Layered Architecture (Sensors - Platforms - Applications): In every domain, we see a multi-layer setup. Cities first ensure pervasive sensing – CCTV, IoT sensors, user smartphones (as data sources) – that feed into central or distributed data platforms. On top of these, analytics/AI layers process information and then interface with either automated actuators or human decision-makers at the application layer. This is essentially a real-world instantiation of the four-layer reference architecture (Samih, 2019). For example, in traffic: cameras (sense) - city data platform with AI (analyze) - traffic light controllers & traveler information (act/orchestrate) → monitoring dashboards and periodic audits (accountability). Technical integration often happens via APIs and data standards: cities like Vienna and Helsinki champion open standards (ISO 37120 for city data) to allow interoperability. This is critical – Deloitte's study noted that without integration, 30% of smart city initiatives might lose public support by failing to deliver holistic services (Deloitte, 2021). All the cities doing well have an integrated data infrastructure supporting these AI agents (Yigitcanlar et al., 2024).

2. The "City Brain" and Orchestration: Many cities are converging on the concept of a central command center or platform that orchestrates multiple services. Cascais's C2 platform with CitySynergy is one example; Singapore's comparable system is its Smart Nation Sensor Platform and associated control centers; Dubai has a Smart City Command Centre as well. These act as nerve centers where inputs from various AI agents come together and decisions can be made in context (e.g., a traffic incident AI triggers a response that also notifies the public transit AI to expect more passengers, etc.). This orchestration role is essentially the "O" in SAOA – ensuring that insights lead to coordinated action across departments. A notable pattern is that these platforms often include Digital Twin visualizations – to see all assets and incidents geographically – and AI-driven correlation engines to spot links between, say, a power outage and traffic jams (if a traffic light lost power).

3. Advisory Agents vs. Autonomous Agents: Across domains, some AI agents serve as advisers (decision support) while others autonomously act on the environment. We observed a general tendency: the more human impact a decision has, the more likely the AI is in an advisory role. For instance, in policing and legal domains, AI suggests or drafts, but humans decide, such as PROMETEA's legal docs (Barrio, 2023) or North Carolina's use of chatbots to answer FAQs but humans for complex queries (Nirala et al., 2022). In contrast, in technical realms like traffic light control or HVAC adjustments, we are comfortable letting AI act autonomously within set parameters. This delineation aligns with "human-in-the-loop" design principles widely recommended in government AI usage (Kumar et al., 2024). An emerging concept is "Minimal Viable Autonomy (MVA)", referenced in governance research (Agentic Foundry, 2025), which suggests giving AI agents autonomy only to the extent that they can be proven safe and effective, and keeping humans in command of consequential decisions. Our case cities implicitly follow this: they automate the routine and the technical but keep human oversight on the strategic and sensitive.

4. Accountability and Governance Mechanisms: A clear trend is that leading cities establish formal governance for AI. Helsinki launched an AI Register – a public listing of all AI systems the city uses, describing their purpose and safeguards (it includes their procurement chatbots, parking enforcement AI, etc.). This transparency builds trust. Seoul, as noted, passed an ordinance and is doing third-party verification for its emergency AI (Visave, 2025). Singapore has an AI Governance Framework (though national, it trickles to city practices) emphasizing transparency and fairness. These measures address accountability: they ensure there's a feedback loop after the "Act" phase. For example, if an AI system issues fines, there's an appeal process; if AI dispatches resources, there's an after-action review to see if it was appropriate; if AI forecasting fails, models are retrained. The cities also engage citizens through open data and participatory tools (like reporting issues via apps that feed AI systems, making the public part of the sensing layer in a way). This collaborative governance is part of what Eden Strategy's ranking captured: top smart cities have people-centric approaches and supportive programs around technology (Sholihat and Yavuz, 2024).

5. Performance Improvement and Learning: Finally, all these AI deployments focus on measurable gains – service time reductions, accuracy improvements, cost savings, etc. We have cited many: 20% faster here, 30% less cost

there. What's important is that cities track these to justify scaling AI. They treat implementations as experiments that must prove value. For example, Dubai's AI in traffic showed enough reduction in accidents or delays to move from pilot to wider implementation. Buenos Aires measured Boti's usage and found enough success to keep expanding its features. This data-driven evaluation is a key part of operational maturity. It reflects a shift to what one might call "Governance by KPI", where city leaders insist on evidence of public value from tech investments, aligning with the idea of Governance Intelligence merging strategic goals with digital innovation outcomes.

Cross-domain analysis reveals that while AI agents may be tackling very different problems, the underlying approach is remarkably consistent. Cities build robust sensor and data foundation, apply AI to glean actionable insights, integrate those into workflows via orchestration platforms, and maintain human oversight and evaluation. This is effectively an AI-enabled continuous improvement loop in city operations. Each cycle of Sense-Analyze-Orchestrate-Act yields data on what happened, which is reviewed (Accountability) and fed back to refine the next cycle. The cities that embrace this loop – turning raw data into intelligent action and then learning from the outcomes – are those seeing tangible improvements in operational performance and service quality.

5. Conclusion

AI agents are increasingly at the heart of smart city operations, driving improvements across transportation, safety, infrastructure, public services, and environmental management. Through this comprehensive analysis of global deployments – from Seoul's emergency callbot to Singapore's traffic AI, from Dubai's smart governance initiatives to Helsinki's digital twin – we have illustrated how AI systems can enhance urban efficiency, responsiveness, and sustainability. Key findings and takeaways include:

- Measurable Performance Gains: Cities employing AI agents report significant operational gains. Urban mobility saw travel times cut by 15–25% and transit reliability boosted. Public safety implementations contributed to faster emergency response (Seoul's 119 AI handling thousands of calls with zero wait) and possibly lower crime through better resource targeting. Administrative AI (chatbots, automated permitting) accelerated service delivery (legal document drafting down from 90 min to 1 min) and cut routine workloads by half or more. In environmental management, AI-driven optimizations led to energy savings (10–30% in pilots) and reduced emissions (e.g. 500,000 tons CO_2 less annually in Singapore's transport sector).

- Technical Integration and Architecture: Successful deployments share a layered, integrated architecture aligning with the SAOA model. They combine extensive sensing (IoT, cameras, citizen inputs) with centralized data platforms and AI analytics, and crucially, they integrate these into operations via unified command centers or workflows. This integration prevents siloed "point solutions" and enables city-wide orchestration – exemplified by Cascais' command center linking 30+ service partners through one platform. The architecture is often visualized through digital twins or dashboards, providing a common operating picture to decision-makers. Our analysis underscores that technology integration – ensuring all parts (data, AI, process) work in concert – is a determinant of real operational impact.

- Agentic Roles – Sensing, Advisory, Orchestration, Accountability: AI agents fulfill various roles in city operations. Some act as sensors, automatically detecting events (traffic incidents, crimes, infrastructure faults) faster than humans. Others serve in an advisory capacity, analyzing complex data to support human decisions – for instance, predictive models suggesting optimal maintenance schedules or policy choices. Many agents have an orchestration role, coordinating across subsystems: we saw AI synchronizing traffic lights citywide, dispatching multi-agency emergency response, and balancing electric grids. Finally, accountability mechanisms are being built around these agents: cities implement oversight committees, audits, AI registers, and ethical guidelines to hold AI systems to public standards. This ensures that as autonomy increases, systems remain aligned with human values and legal norms. The concept of Governance Intelligence is reflected here – cities that pair technological capability with strong governance (vision, leadership, citizen engagement) achieve superior outcomes. Thus, technology and governance must advance hand-in-hand.

- Multiple Domains, Common Principles: While domains from mobility to waste differ, our cross-case comparison revealed common principles: data-driven decision-making, proactive intervention, and continuous learning. AI agents enable cities to shift from reactive fixes to proactive management – fixing issues before citizens notice them (potholes repaired ahead of complaints, pollution alerts issued ahead of smog). They also enable a feedback culture: operations are instrumented and measured so policies can be adjusted dynamically. In short, AI is helping cities move towards what might be called "responsive cities" – urban systems that sense and respond to changes in real time, much like a living organism maintaining homeostasis.

- Global Lessons with Local Adaptation: The cases spanned highly digital cities (Singapore, Dubai) to those in developing contexts (Medellín). The encouraging sign is that AI can deliver improvements in both, but strategies differ. Wealthier cities invest heavily in infrastructure and custom platforms; resource-constrained cities often leverage cloud services or open-source tools and focus on narrow-impact projects first (like Medellín's transit integration or Buenos Aires' chatbot). The success in Buenos Aires with Boti and Prometea shows that local innovation (often with local tech talent) can produce context-appropriate AI solutions. This counters a narrative that smart city tech must come from big vendors – on the contrary, building local capacity (AI teams in city hall or local startups) is key for long-term sustainability and self-determination in technology use. Cities should share best practices in forums and replicate what works, while tailoring to their legal, cultural, and infrastructural context. Our analysis of Seoul, Singapore, Dubai, etc., provides a menu of proven AI use cases that other cities can consider with appropriate localization.

Looking ahead, the integration of AI agents in city operations is likely to deepen. Emerging technologies like edge AI and 5G will enable even faster local decision loops (e.g. traffic drones coordinating instantly with signals), and large language models may empower more sophisticated city chatbots and decision aids (as seen by some cities experimenting with GPT-type tools for drafting policies or summarizing public feedback). The concept of the "100% AI city" (Dubai's 2031 vision) where virtually every service is augmented by AI is ambitious but on the horizon. However, this future should not be about AI replacing human governance, but rather augmenting human capabilities and enhancing urban intelligence. The risk of over-reliance or misuse (e.g. surveillance excesses, algorithmic bias in resource allocation) must be mitigated through robust governance frameworks – essentially, maintaining the accountability in SAOA. AI agents demonstrated clear value in making city operations smarter: more efficient, predictive, and user centric. Cities that strategically deploy these agents – while measuring outcomes and involving stakeholders – are seeing improvements in quality of life for residents and optimization of municipal resources. As smart city programs mature, success will be defined not just by the novelty of AI, but by the measurable public value it delivers. The cases of Seoul, Tallinn, Dubai, Singapore, Helsinki, Medellín, Buenos Aires and others provide a roadmap: invest in data and AI capabilities, align them with strategic city goals, and continuously refine through governance and feedback. Cities are fundamentally service systems, and AI is proving to be a transformative agent in making those services more responsive and effective – truly supporting smart operations for the cities of tomorrow.

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