

Materials Created for Support Work Pertaining to the Deliberation of SCRA 5.0

Uhuru Corporation
2026/02/27



Table of Contents for This Document

Reference in SCRA 4.0

1.	Revision of "Smart City Services" Basic Policy / Case Studies / Implementation Process	Ch. 6, part of Ch. 7, other chapters
2.	Revision of "City OS" Geospatial Data Interoperability Platform / Architecture / NGSi-LD Features / LLM Utilization	Ch. 7
3.	Examination of User Access Methods for Smart City Services Legacy Devices & Methods / Latest Devices & Methods / Issues	No applicable chapter (New addition)
4.	Examination of Open Strategies for NGSi-LD Data Collection Device-agnostic Methods / Smartphones / Broker Connection / Authentication	No applicable chapter (New addition)
5.	Management of Time-Series Data for Digital Twins Handling / QuantumLeap / CrateDB / TimescaleDB / Proposed Configuration	No applicable chapter (New addition)
6.	Expert Opinions Mr. Nagumo, Mr. Nakamura, Mr. Yonezawa	No applicable chapter (New addition)

Background and Key Update Perspectives

Background Overview

In the evolution of industrial and information societies to date, priority has been placed on efficiency, mass production, and speed. This has resulted in many negative effects caused by humans being forced to adapt to systems. In Smart Cities—which aim to realize Society 5.0—we must do more than simply create a society that "highly integrates cyber and physical space" while demanding high IT literacy from its residents. Instead, we are called to transform into a truly human-centric information society where **all people can access services that highly integrate cyber and physical space exactly as they are.**

Key Perspectives

- 1 Issue-focused Smart City services** targeting inclusion.
- Handling of **spatiotemporal data** compliant with the international Standard **NGSI-LD**
- Integration of **City OS** with services using **LLM as a UI**
- Device selection utilizing **natural language** as an inclusive access method
- 5 Open strategies for data collection** via NGSI-LD Brokers.



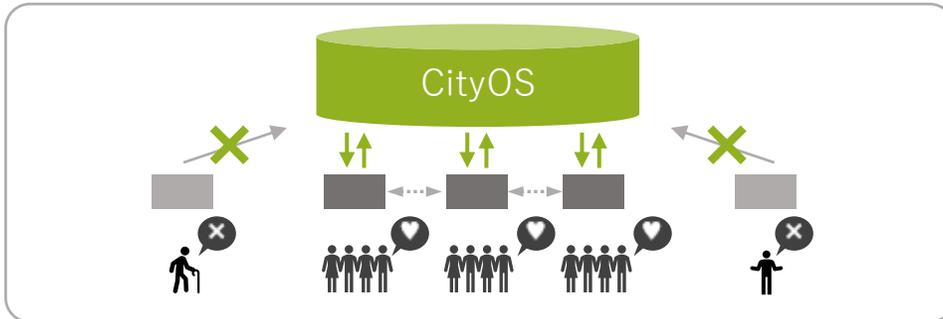
Revision of "Smart City Services"

Shift to Service Design Focused on Issues and Considering Inclusion

This is a concrete version of the review of the Smart City service definition mentioned in SCRA 4.0.

SCRA 2.0

Service design targeting the purchasing demographic



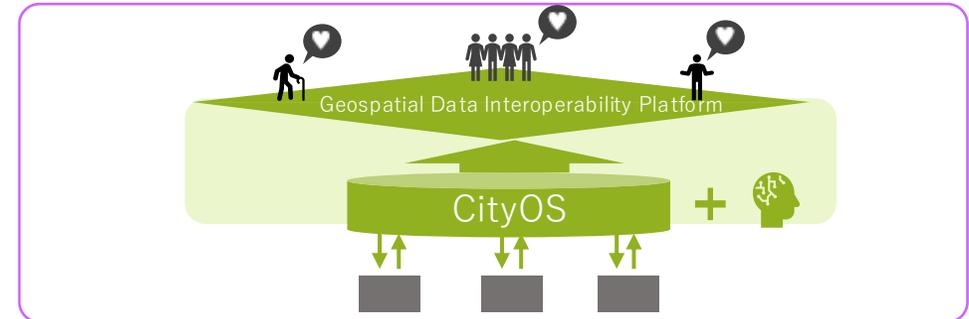
Top-down, centralized design pursuing technical ideals with City OS as a premise. There was little horizontal collaboration, and cases were seen where support failed to reach certain targets. Data remained stored as-is, and updates tended to be scarce.

High dependency on individual services, prone to isolation



SCRA 5.0

Design targeting inclusion



Human-centric, inclusive design aiming to improve Well-being through solving individual issues. Designed for easy access utilizing geospatial data and LLM. By becoming "visible data," updates are also promoted.

Conscious of common touchpoints and cross-sectional utilization



Considering User Literacy, with Natural Language UI as a Standard Prerequisite

The rapid development and adoption of LLMs makes it possible to address inclusion more effectively than ever before

		Early Adopters	Primary Consumers	Children & Youth	Elderly
Smartphone Apps		<p>Will use them. *However, incentive design is required for continued use.</p>	<p>Demand incentives worthy of the effort of use.</p>	<p>There are cases where they do not own one</p>	
	Web Apps				
LLM Utilization	Modern Devices	<p>Will use them proactively. *However, incentive design is required for continued use.</p>	<p>Will show interest. *However, initial introduction is difficult. *Language support becomes easy, expanding the user base.</p>	<p>Difficulty of use can be significantly reduced.</p>	
	Legacy Devices	<p>Conversely, may be skeptical in some cases.</p>	<p>Will use if available on the spot.</p>		



Inclusion Requires Consideration of Individual Characteristics

Not limited to physical characteristics; includes cognitive, linguistic, environmental, and economic factors, which may often overlap across multiple attributes.

Sensory

Visually & Hearing Impaired

Use of text-to-speech, sign language, and Braille, as well as high-contrast UIs and tactile feedback are effective. Consideration must be given to the effectiveness of technical conversions, such as converting text to audio and audio to subtitles.

Mobility

Wheelchair Users / Strollers

Consideration for communication and usage scenarios is required, such as suggesting barrier-free routes during navigation and ensuring low-speed compatibility when deploying autonomous vehicles.

Language

Foreigners / Children

In addition to multilingual support, consideration is required for universal design through pictograms and the use of "Plain/Simple Japanese" for native text.

Cognition

Elderly / Intellectually Disabled

It is important to provide support for those unfamiliar with basic operations through simple interface screens, on-the-spot help functions, and reminder features.

Economic

Non-device Owners

Consideration must be given to utilizing legacy infrastructure such as telephones, as well as public terminals, digital signage, and the maintenance of offline service counters.

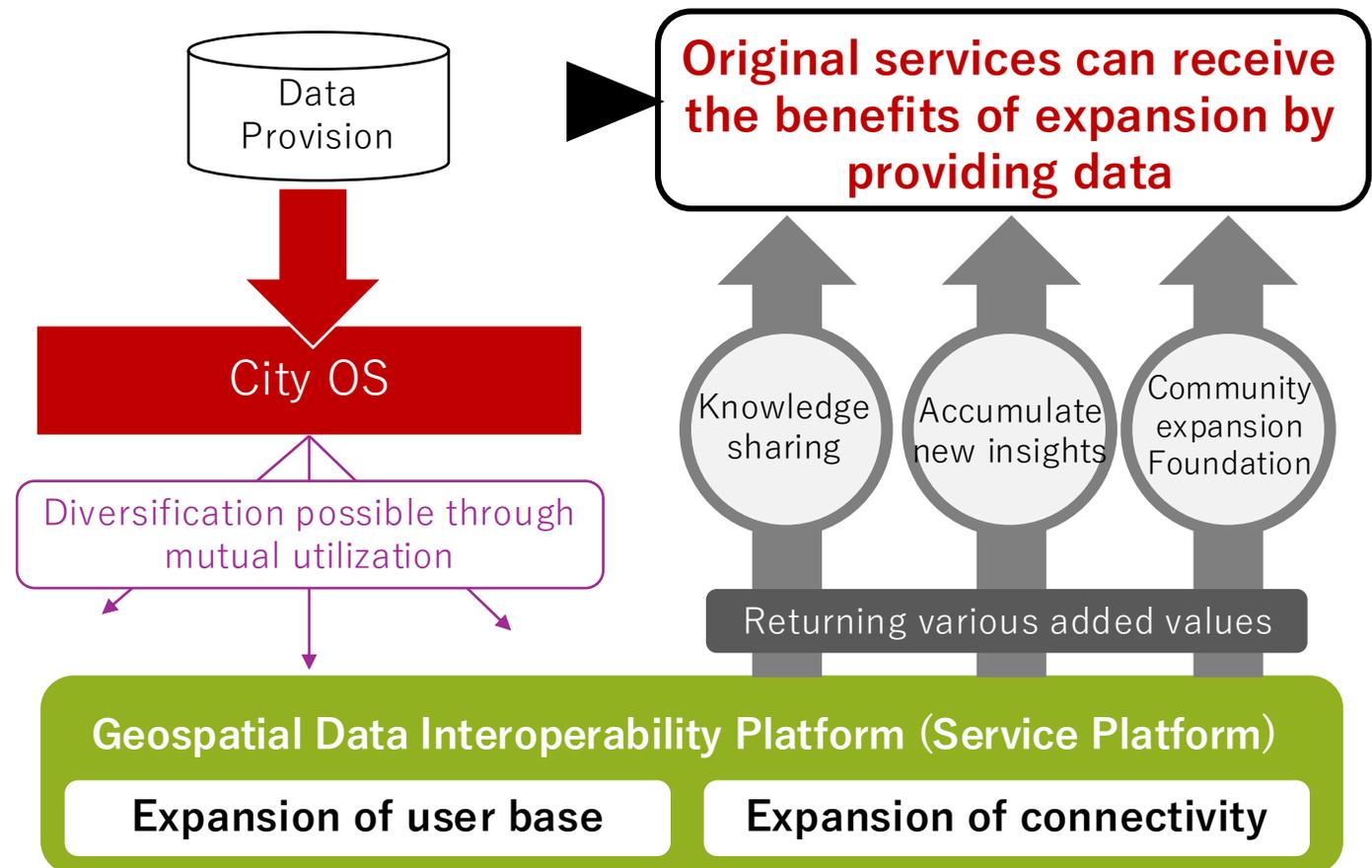
Deployment Envisioning Advanced Forms and Inter-service Collaboration is Critical

We envision utilizing City OS as a mechanism where added value is returned by providing service data.

Start with small steps, envisioning what leads to coexistence and mutual prosperity.

Even data that is insufficient for a single service—such as data for connecting residents' "last mile" or information for providing extra value (+ α) to tourists—becomes useful through multi-layering.

On the other hand, data submitted unilaterally as "just data" is difficult to use. It is necessary to deploy it with meta-information that promotes data utilization, rather than as a simple data catalog, and to allow for expansion through use.





Elements Required for Realizing "Comprehensive Data Consent" by Local Residents

Achieving both a "Prior Sense of Conviction" and "Post-Event Control Rights" necessary for accelerating the circulation of personal data

A. Motivation for Consent

Not only monetary and economic benefits, but contribution to "Regional Contribution" becomes the motivation for consent; prior understanding that the providing partner and purpose of use are acceptable, and the securing of reliability.

Emphasis on Regional Contribution and Visualization of Contribution:

Fostering an awareness that data is utilized not only "for oneself" but "for the region," and continuous visualization of how one's own data is being useful to the region.

Reliability through Third-Party Certification and Prior Understanding:

Ensuring peace of mind and safety through the intervention of third-party review bodies—such as compliance with guidelines or obtaining certification marks—and forming understanding and interest through polite explanations from before the start of service use.

B. Setting "Appropriateness Levels"

Residents do not give comprehensive consent unconditionally; rather, it is a mechanism where they only consent if the "Appropriateness Level (Judgment Criteria)" they have set matches the project conditions.

Detailed Selection based on Basic 3 Conditions and Recipient Attributes:

Application of judgment criteria based on recipient attributes (Public institution/Private, Industry, Capital structure) or the "Exclusion of specific companies," in addition to the basic 3 conditions of "Purpose," "Benefit," and "Data Items."

Fine-grained Settings Based on Life Sphere and Relationships:

Detailed settings for "consent or non-consent" that consider psychological hurdles based on the distance from one's own life sphere, the presence of acquaintances or relatives working there, life realities, and human relationships.

C. Post-Event Control and Safety

In response to comprehensive consent at the entry point, ensuring corrective measures by being able to monitor the flow of data post-event and having a function to stop the linkage at any time (Opt-out).

Reliable Opt-out Rights and Support for Automated Judgment:

In addition to guaranteeing an immediate "Stop data linkage" function based on the user's intent, providing support via an intermediary who automatically cancels the linkage or issues a notification prompting cancellation during periods of project stagnation.

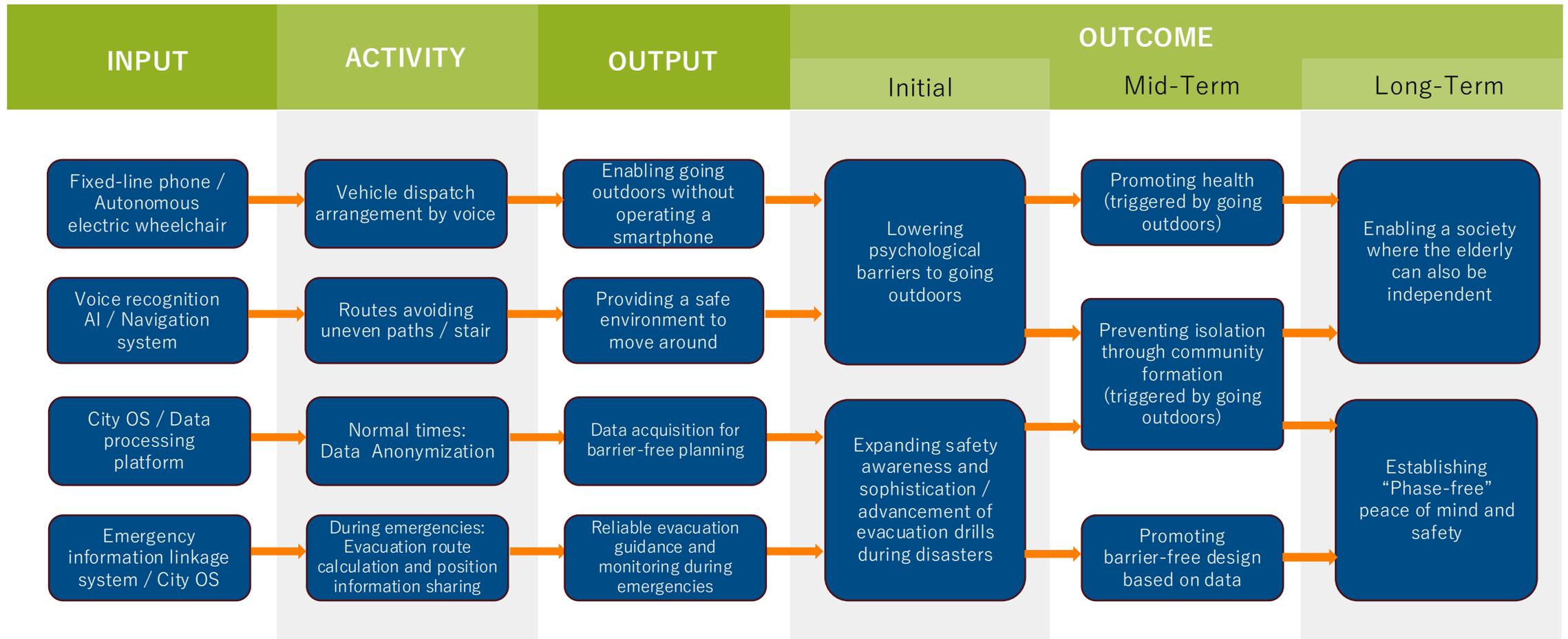
Ensuring Traceability and Access Log Reference:

Providing a highly transparent monitoring function to dispel anxiety regarding unauthorized use by allowing users to grasp "which operator" accessed "what kind" of data and "how" through the provision of access logs.



Toward Service Design that Considers Inclusion through Problem-Focus

Even if it is not possible to equip all functions immediately,
broaden the scope of inclusion response and linkage through step-by-step development.





Domestic and International Case Studies Addressing Inclusion and Cognition

As leading examples, the following are considered relevant reference services with a similar philosophy.

Domestic Case Studies

① Sarabetsu Village Super Village Concept

Digital mutual aid and robot implementation for living
"excitedly until 100 years old" (Sarabetsu Village, Hokkaido)

② "No Writing, No Waiting" Service Counter and AI Consultation Partner

24/7 consultation service utilizing Generative AI
(Yokosuka City, Kanagawa Prefecture)

③ Promoting Utilization through Visualization and Disclosure of Geospatial Data

GIS deployment of open data (Yaizu City, Shizuoka Prefecture)

④ "MLIT Data Platform" MCP Server

An MCP server capable of data searches in a conversational format using natural language, requiring no API knowledge.

Overseas Case Studies

⑤ Monitoring Radar to Find "Isolation" through Data and Human Eyes

Modeling via **NGSI-LD** (Lisbon, Portugal)

⑥ AuroraAI

Push-style administration and AI ecosystem to end "application-based" services (Finland)

1-2-1 Sarabetsu Village Super Village Concept



Aiming to maintain residents' QOL (Quality of Life) and create a sustainable village utilizing digital technology in a region with Japan's most advanced aging and depopulation, under the slogan "Excitement until age 100."

Service Overview

Operator: Sarabetsu Village / Private Enterprise Consortium

Implementation Year: 2020

Target Area: Sarabetsu Village, Hokkaido / Japan

Category: Elderly Support / Depopulation Countermeasures / Robotics

Main Features and Initiatives

● "No Writing, No Waiting" Town Hall (Digital Community Center)

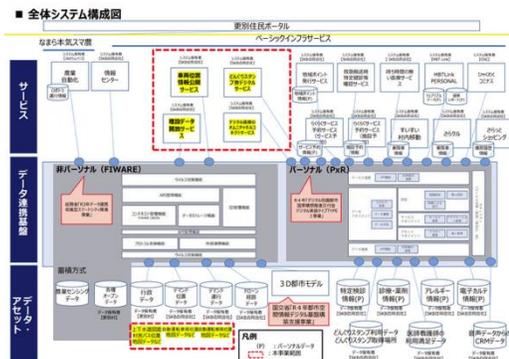
Developed interfaces using TV remote controls and voice interaction so that even elderly people who struggle with smartphones can use them. Established a system where town hall procedures, shopping orders, and remote medicine (online consultation) can be accessed from a home TV, thoroughly focusing on not creating a "digital divide".

● Ensuring Freedom of Movement (MaaS / Autonomous Driving)

Introduced autonomous buses and on-demand vehicle dispatch services as transportation for elderly people after surrendering their driver's licenses. Created an environment where they can move "to where they want to go, when they want to go," aiming to prevent social withdrawal and revitalize the community.

● Foundation Technology: Data Interoperability Platform (FIWARE)

Established a data interoperability platform utilizing the European standard FIWARE. Interlinked health data, movement data, agricultural data, etc., across sectors for use in monitoring, preventive medicine, and smart agriculture (autonomous tractors and drones).

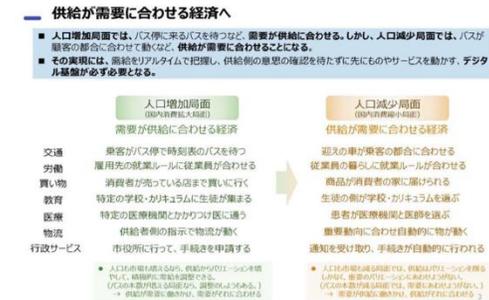


Focus on the Gaps

Design where the system reaches out to the elderly (UI simplification, dialogue via robots) rather than "forcing them to learn operations".

Issue-focused

Solving Japan's structural challenges of "depopulation and aging" through technology, such as transportation after license surrender and alleviating loneliness.



LLM Utilization

Implementation of interactive monitoring robots utilizing Generative AI and voice recognition, and introduction of health consultation interfaces requiring no specialized knowledge.

Key Points

While using cutting-edge technology (AI, robots, autonomous driving), the fact that the user interface is integrated into old devices the elderly are familiar with, such as "TVs" and "voice," is highly regarded as a truly inclusive smart city case study.

1-2-2 Generative AI-powered 24/7 Consultation Service



"No Writing, No Waiting" Service Counter and AI Consultation Partner

Service Overview

Operator: Yokosuka City
Target Area: Yokosuka City, Kanagawa Pref. (JP)
Category: Government DX / Generative AI

Implementation Year: 2023
Standards: NGSi-9 / NGSi-10 (Transitioning to NGSi-LD compatibility)

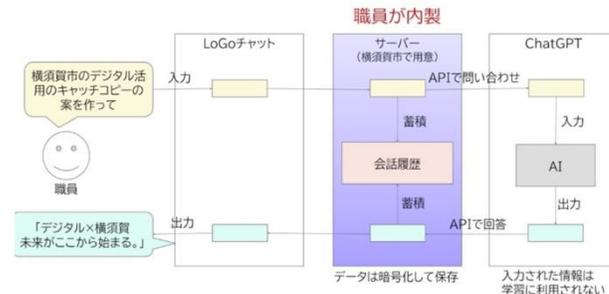
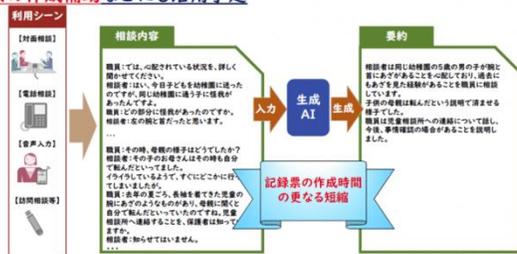
Main Features and Initiatives

In addition to the city-wide introduction of ChatGPT, the city is conducting demonstration experiments for an "AI Consultation Partner" for citizens and application form preparation support at service counters (where AI creates documents based on conversation).

AI: ChatGPT (OpenAI API)
 Interface: LoGo Chat (LGWAN-ASP)
 Network: LGWAN (Local Government Wide Area Network)
 Security: API-based opt-out for training data

実証内容 (相談業務への生成AIの活用)

生成AIを使って対面・電話など相談内容を要約し主訴を生成
 記録票の作成補助などにも活用予定



Focus on the Gaps

AI acts as a "scribe" for elderly and foreign residents who find it difficult to fill out application forms, removing barriers. Designed so that those who are less tech-savvy receive the most benefit when they come to the counter.

- **Emphasis on face-to-face counters:** Rather than forcing online completion, "Application Support Plus" was introduced, where staff operate digital terminals to support visiting residents.
- **Hybrid convenience:** A division of roles based on skill level—those who can use smartphones prepare in advance at home (reducing wait times), while those who cannot receive thorough face-to-face support (input assistance) at the counter.

Issue-focused

Realizing inclusive support by focusing on the "essence of consultation" rather than just efficiency.

- **Removing psychological/physical hurdles:** Inclusion of groups that fell through the cracks of traditional counters, such as foreign residents and citizens struggling at night, through 24/7 AI support and multilingual capabilities.
- **Data visualization and early support:** Building a mechanism for proactive support (outreach) by detecting "signs" before issues become serious through the analysis of data accumulated by the AI Consultation Partner.

LLM Utilization

The point of praise is "**Stealth AI utilization**" that does not make users conscious that they are "using AI."

- **UI/UX Optimization:** Residents do not need to think about LLM prompts; they simply follow a Q&A-style navigation.
- **Significant reduction in staff burden:** In the AI Consultation Partner, staff simply converse as usual. Since the AI creates summaries in the background, the benefits of AI can be enjoyed 100% without special IT skills.

Key Points

Yokosuka City's initiative balances "No Writing = Reduced resident burden" and "No Waiting = Administrative efficiency," positioning AI not as "**cold automation**" but as a tool to supplement "**warm face-to-face support.**"

1-2-3 Promoting Utilization through Geospatial Data Visualization



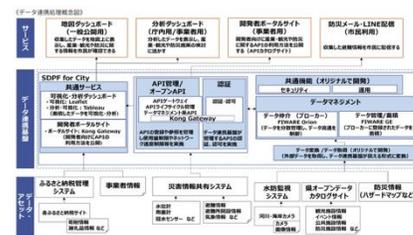
Digital Map Service for Accessing Real-time Disaster and Urban Planning Information Anytime, Anywhere

Service Overview

Operator: Yaizu City / Yaizu City Smart City Promotion Council **Implementation Year:** 2025
Target Area: Yaizu City, Shizuoka Prefecture / Japan **Standard:** NGS1v2
Category: Life & Living Info / Disaster Prevention & Info / Urban Planning & City Building / Tourism & Events

Main Features and Initiatives

- **A digital map for citizens integrating living and administrative information:**
 Consolidates administrative information scattered across sectors such as disaster prevention, transportation, childcare, and welfare onto a single map. It functions as a common platform where citizens can intuitively access the information they need now, used daily and during disasters.
- **Centralization and real-time provision of disaster prevention information:**
 Overlays hazard maps, evacuation centers, river levels, and rainfall information. It supports situational awareness and evacuation decisions during disasters, leading to rapid action.
- **A "no-search" entrance for administrative information:**
 Searchable map for lifestyle information such as public facilities, transportation, disaster mitigation & AED locations. It acts as an entrance to the "Digital City Hall" without requiring complex navigation.
- **Highly scalable open GIS platform:**
 Utilizes an open GIS platform accessible via browsers. This flexible foundation looks toward future sectoral expansion and private-sector collaboration in areas like tourism and urban planning.
- **Implementation that makes the Smart City "easy to understand":**
 Visualizes advanced data in forms usable by citizens. Emphasizes design that makes smart city initiatives feel familiar and relevant.



Focus on the Gaps

Rather than just providing a system, the city sets "improving citizens' awareness of disaster prevention" (a mental transformation) as a KPI (Key Performance Indicator). The process of creating maps or citizens posting information itself serves as disaster training, fostering "Civic Pride" and an increased sense of community involvement.

Issue-focused

Avoids the trap many municipalities fall into of making "using AI" or "creating a 3D city model" the goal itself. System requirements are defined by working backward from final outcomes like "improving citizen disaster awareness" and "creating sustainable communities through mutual aid".

LLM Utilization

Understands the meaning of posted "memos (text)" to infer which category they belong to, such as "inundation," "fallen tree," "fire," or "road damage". It also plays a role in extracting high-urgency posts through severity and sentiment analysis.

Key Points

Transitions the map from "a tool for administration to manage citizens" to a "common language for citizens and administration to understand and protect the area together". While traditional Government DX often ended at operational efficiency ("Defensive DX"), Yaizu City's case steps into "Offensive DX" that creates citizen participation and mutual aid.

Breaking Down the Wall of Specialized Knowledge by Removing the Need to "Search" or "Analyze"

Service Overview

Operator: Yaizu C. / Yaizu C. Smart City Promotion Council

Implementation Year: 2025

Target Area: Yaizu City, Shizuoka Prefecture / Japan

Standard: NGS1v2

Category: Life & Living Info / Disaster Prevention & Info / Urban Planning & City Building / Tourism & Events

Main Features and Initiatives

Previously, utilizing the vast amount of infrastructure data (roads, rivers, urban planning, etc.) held by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) required an understanding of complex API specifications and programming skills. With the **introduction of the MCP server**, AI (such as Claude) can now "talk" directly with this data infrastructure. Users only need to request in natural language, such as "Summarize hazard maps and bridge inspection results around [City Name]," and the AI retrieves, integrates, and analyzes the data in the background to provide an answer.



Focus on the Gaps

The primary measure is opening up advanced administrative data, which was previously accessible only to experts, to ordinary citizens and non-engineer local government staff.

- **Liberation from "Professional Techniques":** Access to data via smartphone or PC chat screens is possible without proficiency in GIS or complex DB operations.
- **Improving Information Accessibility:** For those who want to understand data visually, it bridges the gap in understanding by generating graphs and simple explanations based on the values retrieved by the AI.

Issue-focused

Includes groups that "need data but have no means of utilizing it," such as small-scale construction companies without specific technical skills or community disaster prevention groups.

- **Support Directly Linked to Practice:** For specific and local issues like "Check for obstacles on the drone flight route," it instantly extracts and organizes only the necessary data.
- **Open Ecosystem:** The source code is published on GitHub, allowing private companies to incorporate this mechanism into their own services, boosting the problem-solving speed of society as a whole.

LLM Utilization

Operations are completed using only "everyday language," without users being conscious of technical terms such as "API" or "JSON".

- **The Ultimate No-code:** Data collection and processing, which used to take days to weeks, is reduced to minutes in a conversational format.
- **Acceptance of "Ambiguity":** Even if users do not know the exact terminology, the AI interprets the context and supplements with "Is this what you mean?" This design is unlikely to be affected by differences in search skills.



Human-centric DX: “Smartening the environment around the elderly rather than forcing technology upon them”

Service Overview

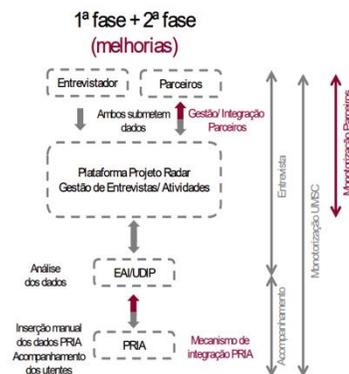
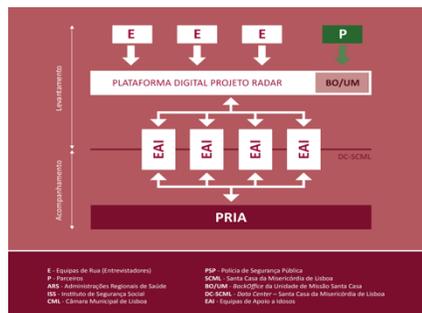
Operator: Lisbon City Council / Sta. Casa da Misericórdia
Target Area: Lisbon / Portugal
Category: Countermeasures for Social Isolation / Data-driven Welfare

Implementation Year: 2019
Standard: NGSI-LD (ETSI GS CIM 009)
Ref URL: www.interregeurope.eu/good-practices/radar-project

Main Features and Initiatives

The RADAR Project is a community-based monitoring system targeting citizens aged 65 and over in Lisbon (especially those living alone or at risk of social isolation). Its most distinctive feature is the seamless connection between "digital (data platform)" and "analog (local residents and merchants)". Neighborhood pharmacies, shops, and residents act as "radars (observers)," reporting any anomalies to a specialized team via a dedicated platform. AI and data analysis are used to determine priorities and facilitate rapid outreach (home visits). The RADAR Project is a deeply human-centric DX (Digital Transformation) that "smartens the environment surrounding the elderly instead of forcing technology on them".

- **Platform:** NEC Cloud City Operation Center (CCOC)
- **Middleware:** FIWARE Context Broker (Orion)
- **Integration:** IoT (Waste, Transportation) + Legacy Systems



Focus on the Gaps

The core of this project is that "those receiving support (the elderly) do not need to operate any devices".

- **Passive Inclusion:** Rather than forcing the elderly to "install an app" or "set up a sensor," the surrounding monitoring network is digitized, allowing them to benefit from monitoring regardless of their digital skills.
- **Supplementing Human Trust:** Technology only supports the judgment of "who should be helped" behind the scenes; the faces that appear in front are familiar neighbors and social workers.

Issue-focused

To address the invisible challenge of "loneliness," which traditional administrative services struggled to reach, the project aims to solve this by "turning the entire community into a sensor".

- **Multi-layered Network:** Currently, over 2,000 local organizations and shops (cafes, pharmacies, etc.) participate. This ensures that everyday feelings of "something is different" (e.g., they didn't come to buy bread, the lights aren't on) are reliably linked to government support.
- **Risk Stratification:** Based on collected data, the situation of the elderly is categorized into levels like "Green, Yellow, and Red". Limited administrative resources can be concentrated on truly high-urgency cases.

LLM Utilization

The system is designed so that even those providing information (shops and volunteers) can operate it with extremely low IT literacy.

- **Intuitive Interface:** The reporting system is completed in minimal steps. No difficult programming or complex data entry is required.
- **AI-driven Triage:** Since AI uses natural language processing to determine the urgency of the vast amount of accumulated reports, field personnel do not need advanced analytical skills.

Push-style Administration and AI Ecosystem to End "Application-based" Services

Service Overview

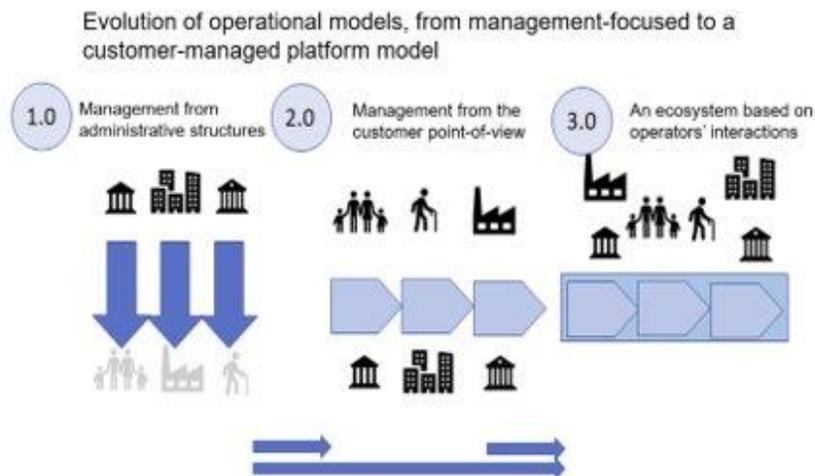
Operator: Ministry of Finance, Finland / Digital and Population Data Services Agency

Target Area: Nationwide (Local government collaboration) / Finland

Category: Government DX / Proactive Services / Life Events **Implementation Year:** 2018

Main Features and Initiatives

AuroraAI is a system where citizens do not "search for administrative services themselves"; instead, AI senses the citizen's situation and "proactively proposes the most suitable services". **Its greatest feature is the interconnection of multiple services across the boundaries of government ministries and private companies for each "Life Event"** (birth, career change, retirement, etc.). For complex issues faced by citizens, AI combines appropriate resources and presents a seamless solution (path). This project transforms government from a "place for procedures" to a "partner for life".



👁 Focus on the Gaps

- **Push-style Support:** Even if the person does not understand the complex structure of administrative organizations, the AI actively reaches out, saying, "You need this benefit and this support program now," preventing disadvantages caused by information gaps.
- **Human-centric:** Designed to support life milestones rather than putting technology at the forefront. Users experience something closer to receiving a "guide" rather than "operating" a digital tool.

🎯 Issue-focused

Traditional administration was divided (e.g., "Health is the Ministry of Health," "Education is the Ministry of Education"), but AuroraAI focuses on the "complex issues faced by a single human being".

- **Comprehensive Life Event Support:** For example, regarding the issue of "unemployment," it provides not just a benefit payment, but re-education, mental care, and housing support from different organizations as a single flow (path).
- **Predictive Inclusion:** Predicts future risks based on accumulated data. By intervening preventatively before falling into hardship, it prevents social isolation before it happens.

🧠 LLM Utilization

- **Communication via Natural Language:** Citizens do not need to memorize technical terms; by simply explaining their current situation in natural language (e.g., "Recently, my body doesn't move as I'd like, and I'm anxious about the future"), the AI matches it with necessary services behind the scenes.
- **Benefits of a Decentralized Network:** No special environment setup is required on the user side. By simply interacting with an AI agent through a browser or existing smart devices, users can enjoy the benefits of advanced data integration.

Validation and Verification of Design Guidelines in SCRA 5.0

Survey Objective

Verified the validity of the design guidelines (eliminating digital exclusion, AI support, and retrofitting) in SCRA 5.0 by examining 27 sources, including domestic and international academic papers and international standards.

Survey Perspectives

- **Eliminating Digital Exclusion:** Positioning vulnerable groups not as peripheral entities, but as the starting point (origin) of design.
- **Cognitive Support:** Utilizing LLMs to infer the user's context and provide proactive, personalized support.
- **Effective Utilization of Existing Infrastructure (Retrofitting):** Including and expanding existing social customs and legacy systems through digital means rather than rejecting them.



Validation and Verification of Design Guidelines in SCRA 5.0

Survey Results

- Reviewed the literature listed to the right and confirmed consistency with the design guidelines.
- The primary insights obtained are summarized in the table below.

Perspective	Traditional Issues	Solution by SCRA 5.0 (Grounds for Validity)
Paradigm Shift	Overemphasis on functional supplementation (e.g., audio output of information).	Psychological & Social Transformation: Cultivating an "attitude" to counter discrimination and prejudice, and redefining residents as co-creators.
AI Agent	"Pull-style" where residents must search and operate systems.	Ambient Inclusion: Realizing "Zero-Click" support where sensors and LLMs collaborate, making operations unconscious.
Implementation Approach	Full renewal to the latest technology.	Conceptual Retrofitting: Overlaying LLMs as advanced interfaces on existing systems to upgrade cities at low cost.
Trust & Data Sovereignty	Lack of transparency and sovereignty.	Engineering Assurance of Accountability: Explaining the grounds for judgment in natural language to ensure transparency compliant with international standards. Balancing data sovereignty and dynamic security through decentralized access control using Verifiable Credentials (VCs).

■ Literature & Reports (18 items)

- **Busciantella-Ricci et al. (2023):** DxlA Framework for Attitude Cultivation
- **Hu & Bock (2025):** Paradigm Shift toward Human-centricity in Smart Cities
- **Zhang et al. (2025):** Dynamic Identification of Latent Resident Needs via LLM and BERTopic
- **Makkonen & Inkinen (2024):** Institutionalizing Governance Participation by Persons with Disabilities
- **Burlando et al. (2024):** IoT Smart Cane & AI Navigation for the Visually Impaired
- **Harding (2020):** Collaborative Experience Design with Diverse Users in Subways
- **Park et al. (2025):** Reconstructing Social Capital for the Elderly via Living Labs
- **Wang, Z. (2024):** Evaluation of Service Implementation Based on Resident Needs in Fujisawa SST
- **Ran An (2024):** The Need for Japan's Unique Smart City Model (Retrofitting)
- **Hosokawa, Y. et al. (2022):** Consensus building support for non-experts utilizing MR (Mixed Reality)
- **Zhang et al. (2025):** Proactive Context-aware Support via ContextAgent
- **Spathis et al. (2025):** "Conceptual Retrofitting" of Existing Infrastructure
- **He et al. (2025):** Building Trust with Residents via Explainable AI (XAI) in Building Management
- **Lin et al. (2025):** Web-based Consensus System for the Elderly (Access Minimization)
- **GoodData (2025):** Zero-click Decision Support "Agentic Analytics"
- **Tang et al. (2024):** Generative UI for Dynamically Generating Individual UIs
- **Amouzadeh et al. (2025):** UX Design Review for the Elderly (Voice Operation & Error Tolerance)
- **Fotiou et al. (2025):** Establishing Decentralized Access Control and Data Sovereignty using Verifiable Credentials

■ Standards, Guidelines & Tools (9 items)

- **OECD (2020):** Data Governance with Resident Well-being as an Index
- **UN-Habitat (2025):** International Guidelines for Digital Human Rights and Civic Participation
- **ISO 37106 (2021):** International Standard for Citizen-Centric Operating Models
- **UN-Habitat (2022):** Practical Action Plan for Bridging the Digital Divide
- **Eurocities (2022):** Examples of Disability Inclusion and Public Procurement Requirements in European Cities
- **WEF (2019):** Technology Governance Model seeking "Inclusion by Default"
- **Jensen et al. (2023):** Living Lab Co-creation Model Adapted to the Japanese Cultural Context
- **G3ict (2017):** Toolkit for Evaluating Digital Inclusion in Cities
- **JST (2021):** Objective Evaluation Kit for User Experience (UX) using Wearables

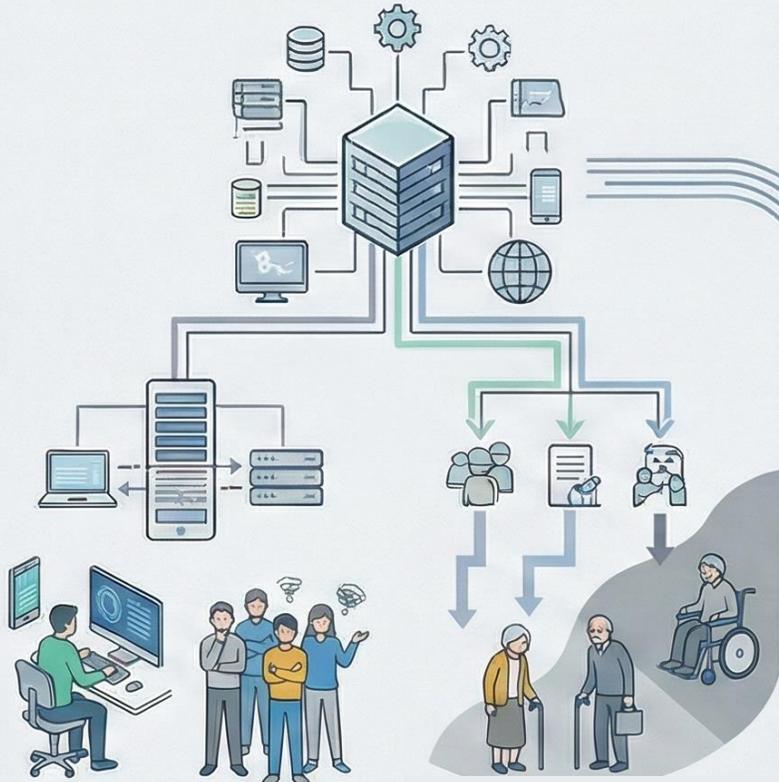


Section 2: Revision of "City OS"

2-1-1 City OS: From "System-centric" to "Human-centric"



Challenges up to SCRA 4.0: System-centric Design



Requires high IT literacy from residents:

Designed with a priority on inter-system coordination, which only a segment of users could master.

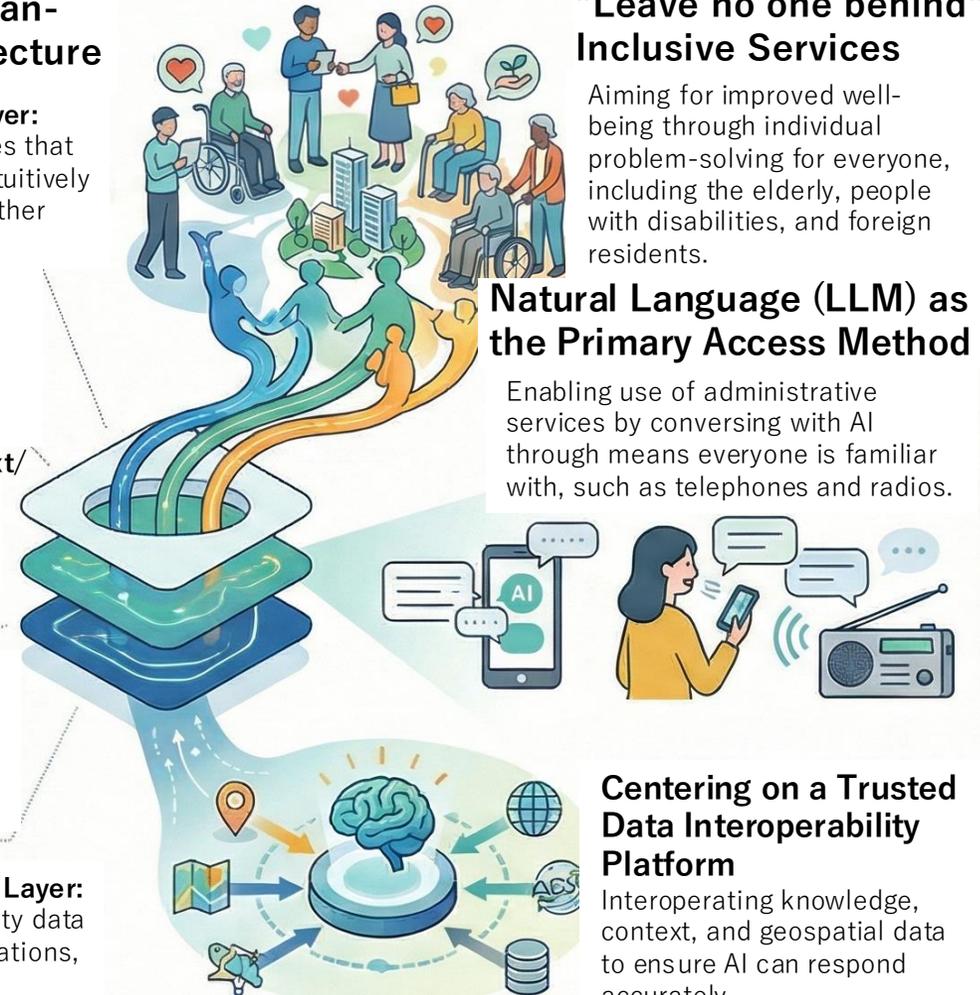
Insufficient response to "gap" issues:

People who are difficult to reach with support, such as the elderly and individuals with disabilities, tended to be excluded from service targets.

Vision for SCRA 5.0: Transition to Human-centricity

SCRA 5.0 Human-Centric Architecture

- ⑤ **Interface/UX Layer:** Providing experiences that residents can use intuitively via voice, text, and other means.
- ④ **Access Control/Governance Layer:** Managing complex permissions for LLM utilization.
- ③ **Semantic Context/Knowledge Layer:** The "brain" of the City OS, where knowledge and context are accumulated.
- ② **Geospatial Data Interoperability Layer:** Anchoring all spatiotemporal facts within the city.
- ① **Data Generation Layer:** Acquiring dynamic city data from sensors, applications, and more.



"Leave no one behind" Inclusive Services

Aiming for improved well-being through individual problem-solving for everyone, including the elderly, people with disabilities, and foreign residents.

Natural Language (LLM) as the Primary Access Method

Enabling use of administrative services by conversing with AI through means everyone is familiar with, such as telephones and radios.

Centering on a Trusted Data Interoperability Platform

Interoperating knowledge, context, and geospatial data to ensure AI can respond accurately.



[L-5] Interface/UX Layer (Human-centric UI/UX Layer)

Role: Interpretation, Summarization, Explanation, Responsibility Boundaries
Technology: LLM, TTS/ASR, MCP Server/Host/Client

Providing an experience where residents can intuitively use services via voice, text, etc.

[L-4] Access Control/Governance Layer (Social Authorization Layer)

Role: Access Control, Governance, Policy Enforcement
Technology: ReBAC, ABAC, PBAC

Performing complex permission management for LLM utilization.

[L-3] Semantic Context/Knowledge Layer

Role: Knowledge Graph, Knowledge Base, City Brain
Technology: NGSi-LD, Vector DB

The brain of the City OS that accumulates knowledge and context.

[L-2] Geospatial Data Interoperability Layer

Role: Anchoring of spatiotemporal facts, integration of various data
Technology: QuantumLeap

Anchoring all spatiotemporal facts within the city.

[L-1] Data Generation Layer

Role: Sensing, IoT, various input data, source of facts
Technology: Sensor, IoT

Acquiring dynamic city data from sensors, applications, etc.

LLM is an "Interface," not a "Decision Maker"



Role 1: Translator

- Converts the "natural language" of citizens into "queries (commands)" that the City OS can understand.
- Summarizes the "structured data (JSON-LD)" output by the City OS into "text" that citizens can understand.



Role 2: Explainer

- Fulfills accountability by presenting the data source (when and where the data is from) that served as the basis for the answer.

Governance Constraints

- **Read-Only Principle:** As a rule, the LLM does not have the authority to directly overwrite master data within the City OS.
- **Human in the Loop:** For important decision-making, such as administrative procedures, a final confirmation process by a human must always be involved.

Coordination Between the Inside and Outside of the City OS Enables a "Human-centric City"

MCP Server



Role: Toolbox (Tools)

Direction: The side being used

Layers: 2, 3, 4

In addition to the roles traditionally provided by City OS APIs, it provides city data and functions as "Tools" to external AI agents, publishing resources in a format that AI can easily understand (MCP).

MCP Host / Client



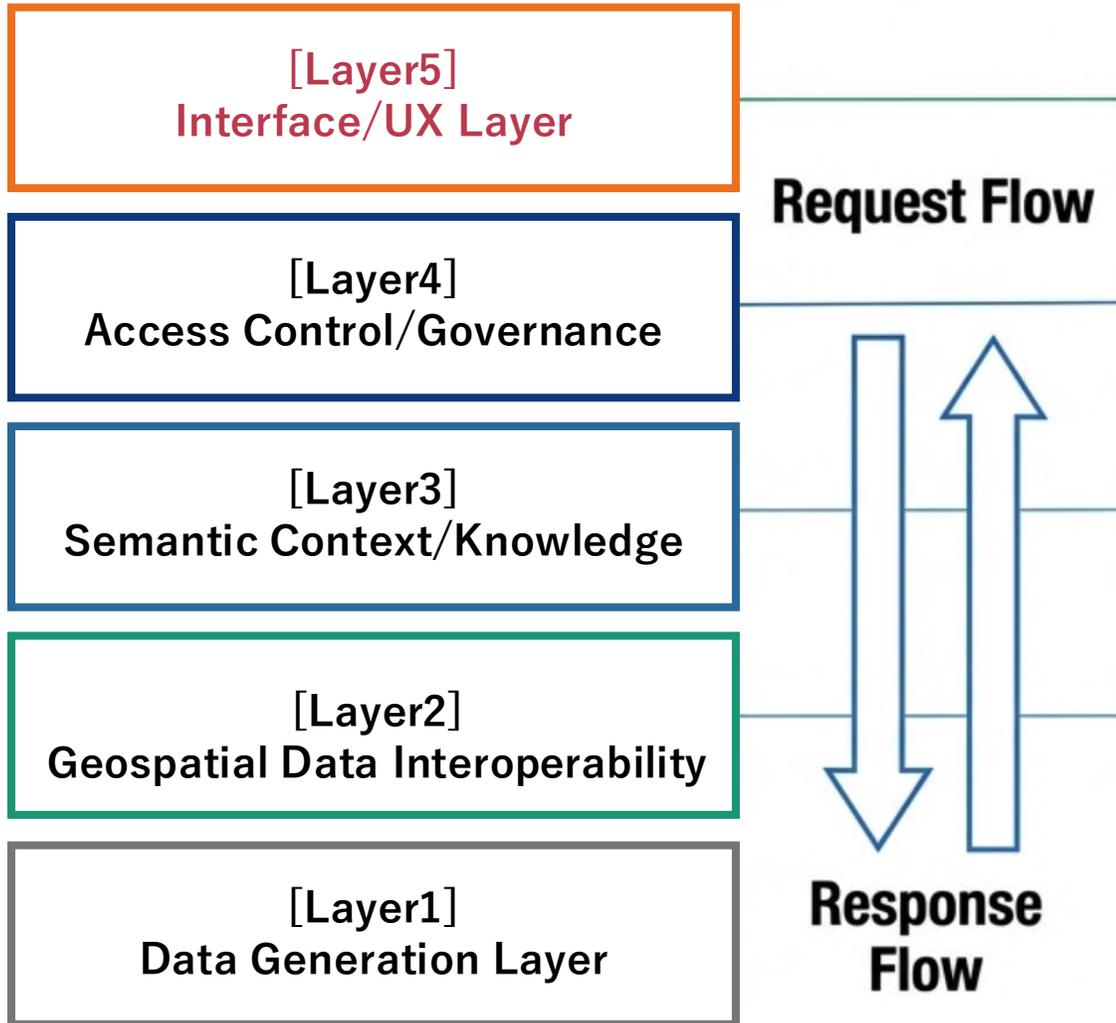
Role: Conductor / Executer (Host / Client)

Direction: The using side

Layer: 5

Functions as an MCP Host that receives natural language input from users (citizens) and executes the LLM/AI agent representing them, enabling the use of external MCP servers based on the agent's judgment.

For the City OS to evolve from a "mere database" to a "dialogue partner for citizens," not only MCP server functions but also MCP host/client functions for leveraging external intelligence are essential.



MCP Host / Client

Receiving user input, connecting to external MCP servers, and presenting available tools.

Permission Check



Intercepting external MCP requests, performing permission checks via PBAC/ABAC/ReBAC, and masking personal information.

MCP Server (Resource)

Entities of "Tools" providing meaning and context (e.g., get entity relationship).

MCP Server (Resource)

Entities of "Tools" providing facts and location information (e.g., search shelter location).

Controlling "Who is allowed to know what"

What does it mean for an LLM to become a citizen

Citizens query the City OS in natural language (e.g., "Where is the shelter?"). However, the LLM does not know **"who is allowed to ask that."**

There is also a risk of **hallucinations**.

Necessity of Governance

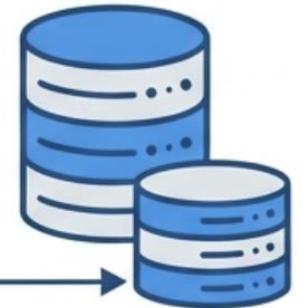
Instead of letting the LLM make judgments, a governance layer is required to filter and present only the "facts allowed to be seen" beforehand.



Access Control / Governance Layer [Layer 4]



City Data

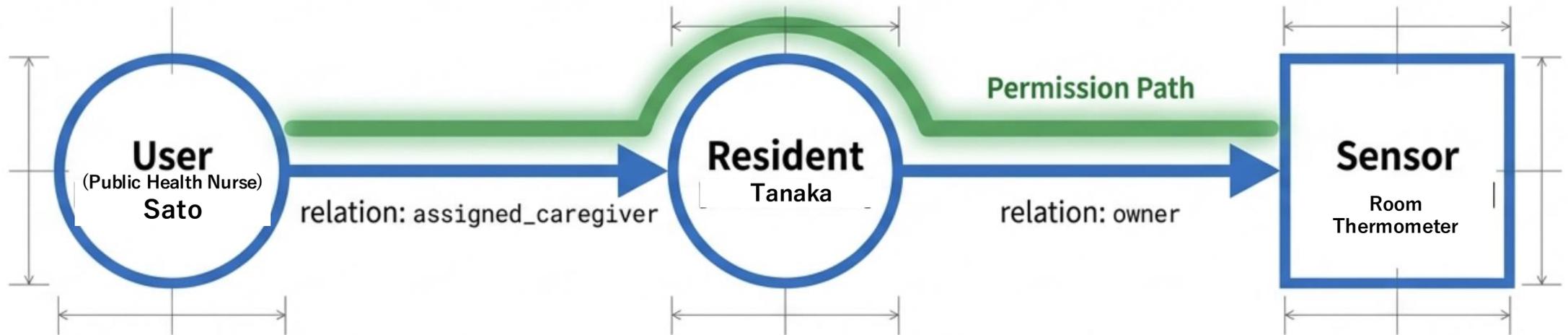


Diverse Entities and Proxy Access

The elderly, people with disabilities, children, and foreigners do not always access via their own devices.

It is essential to have a mechanism (ReBAC) that maintains publicly verifiable relationships—such as "family," "welfare commissioner," "care manager," and "supporter"—in a system-level graph structure to legitimately authorize proxy access.

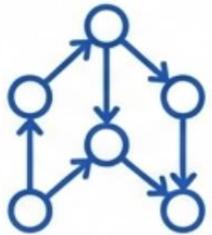
Use Case: Data Access in Elderly Monitoring



1. **Relationship Definition:** Synchronize NGSI-LD entity relationships with the ReBAC platform (e.g., SpiceDB).
2. **Traversal:** Determine via graph search: "Does Sato have viewing permission for the sensor via Tanaka?"
3. **Result:** Access is granted only when the relationship is verified.



ReBAC is Essential for Proxy Access to LLMs



ReBAC (Relationship-Based)

Control based on
"Relationships"

Human-to-human connections,
ownership, assignment relationships,
etc.

“
"Is the user the public health nurse
taking care of Tanaka?"
”

Highly compatible with the NGSI-LD
graph structure.



PBAC/ABAC (Policy-Based/Attribute-Based)

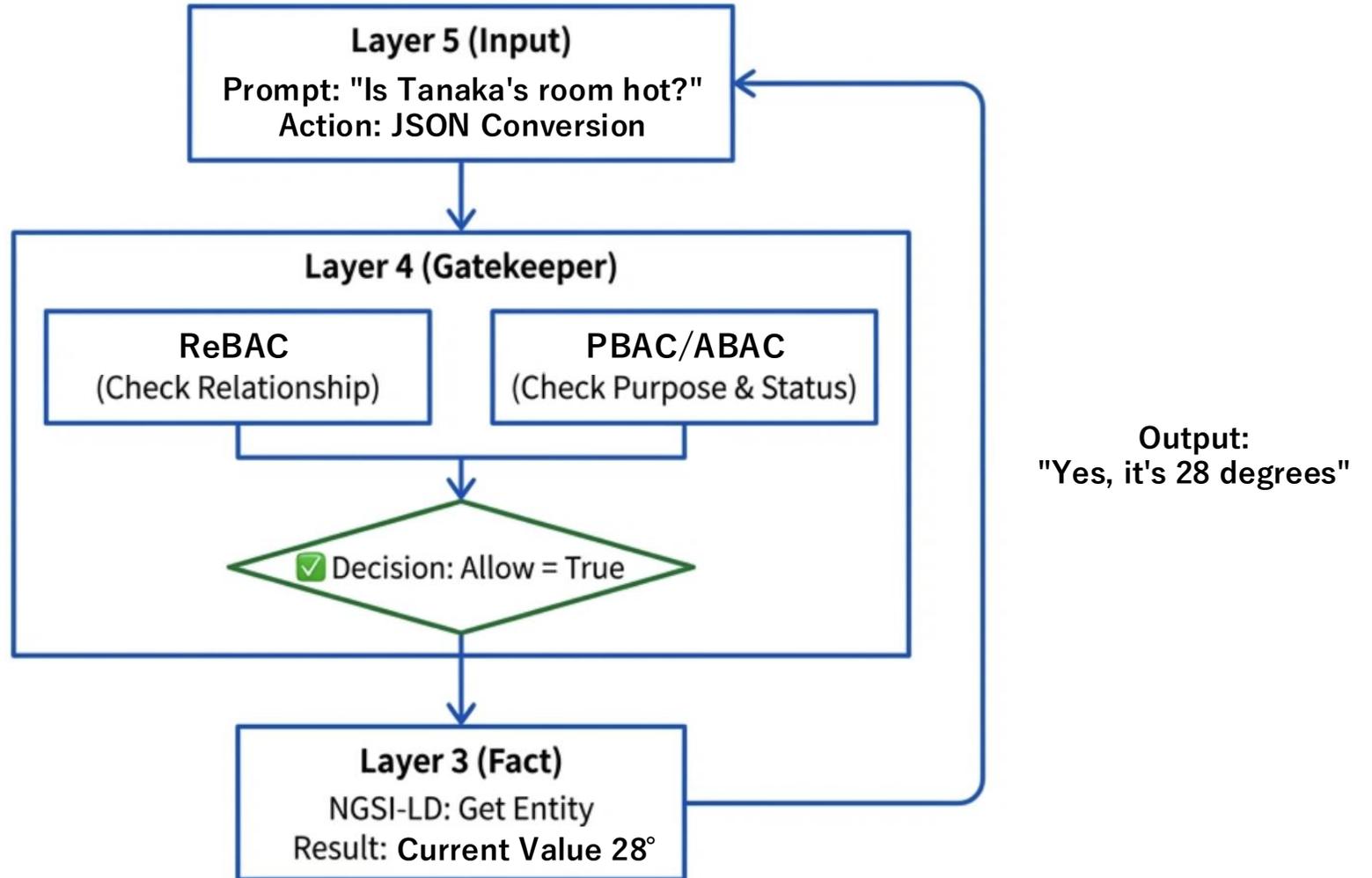
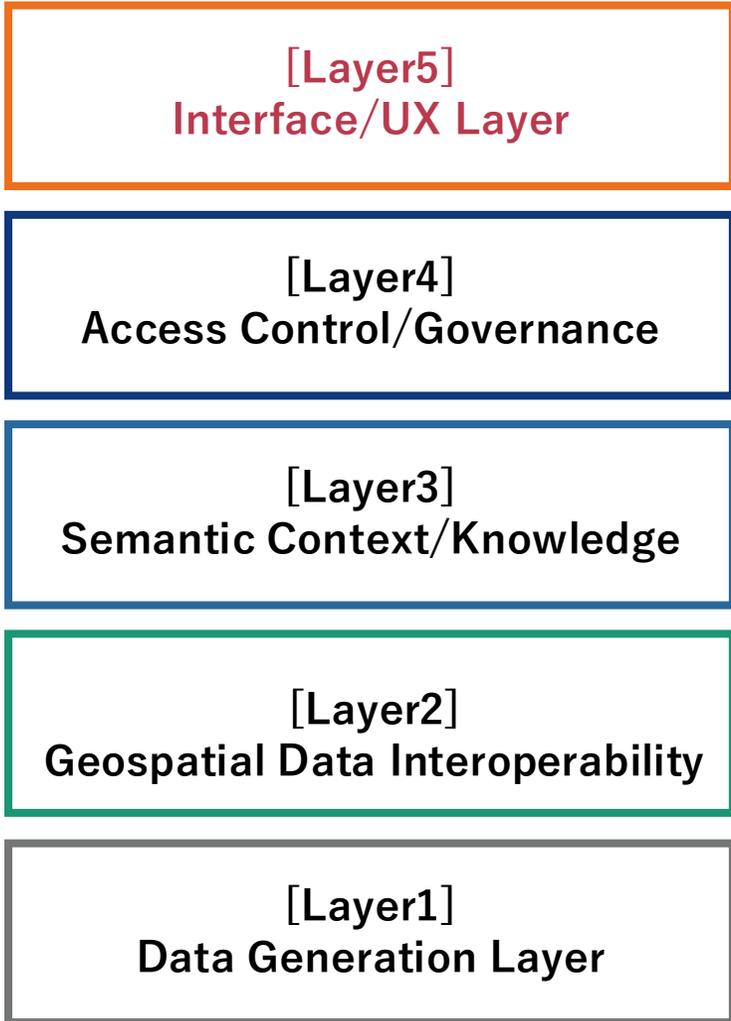
Control based on
"Attributes, Purpose, and Situation"

During disasters, emergencies,
purpose of use (rescue/statistics), etc.

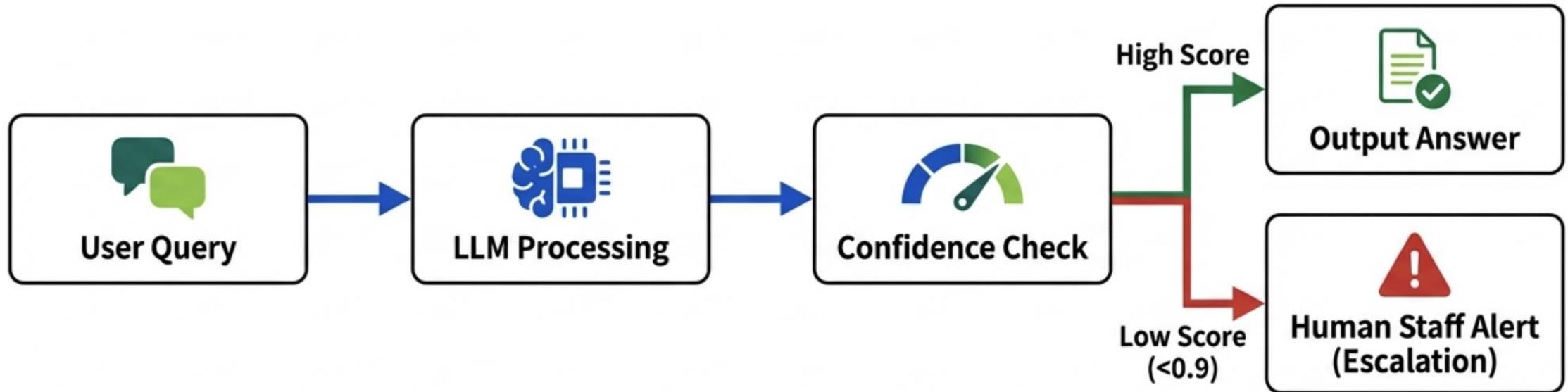
“
"Is a disaster currently declared, and
is the purpose life-saving?"
”

Strong in dynamic context evaluation.

2-3-4 Logical Flow of Access Control Combining ReBAC and PBAC/ABAC



Retaining the "Chain of Thought" as Audit Logs to Explain how Answers were Derived



Strict Audit Logging

- The reasons behind an LLM's response often become a "black box." It is necessary to have a function that saves and presents the path taken through the Knowledge Graph to reach the conclusion as a log.

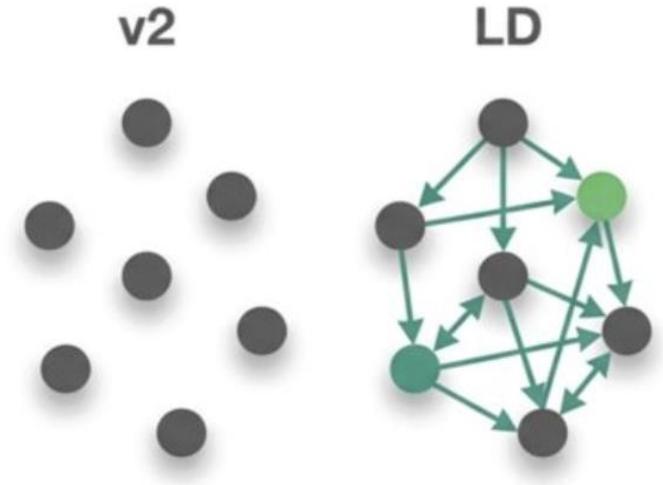
Escalation from LLM to Human

- For responses involving "strict legal responsibility," such as those regarding residents' rights and duties, the system must have a function to stop the LLM's automated response and forcibly trigger an escalation flow to administrative staff.



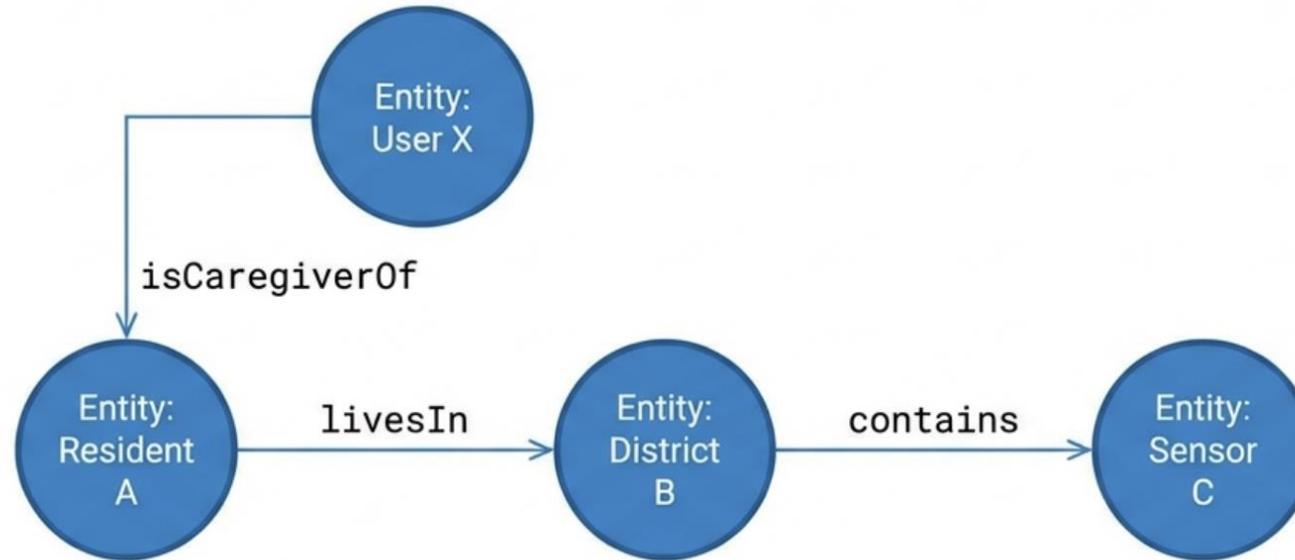
The Necessity of NGSi-LD for AI to Understand Context

Comparison Item	NGSI-v2	NGSI-LD
Structure	Attribute-centric model	Property Graph (Linked Data)
AI Recognition	Without intervention, "Data A" and "Data B" are treated as separate entities.	Recognizes that "Data A" is influenced by "Data B."
Limitations / Advantages	Requires intentional documentation of relationships.	Data structure that makes it easy to trace city states and relationships (Traverse).
Interoperability	Tends to become local rules.	Standardized semantic interpretation based on international standards (@context).



For City OS to leverage LLMs, it is crucial to manage data not just as mere numbers, but as knowledge with meaning. NGSi-LD is one of the standard specifications for this purpose and serves as an effective foundation for consistently describing and sharing the city's context.

The True Value of NGSI-LD's "Graph Structure"

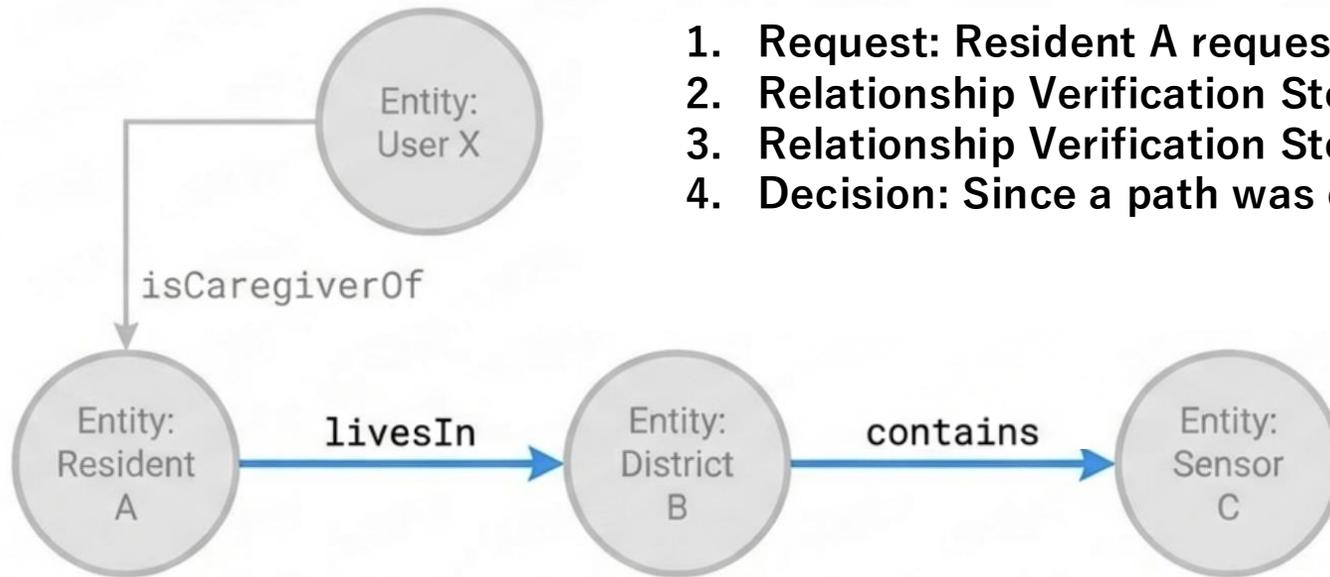


Unlike traditional RDB or CSV (tabular formats), in NGSI-LD, the data itself possesses “connections (Linked Data).”

- Relationship Property: Utilizing the 'Relationship' property, which is a standard specification of NGSI-LD.



ReBAC and Relationship Graphs can Share the Same "Graph Structure"



1. Request: Resident A requests the "current river water level."
2. Relationship Verification Step 1: Resident A livesIn District B.
3. Relationship Verification Step 2: District B contains Sensor C.
4. Decision: Since a path was established, access is "Permitted (Allow)."

Layer 4, the Access Control/Governance Layer, uses ReBAC to verify if a "path (route)" exists from the subject to the object (Graph Traverse). Authorization decisions are made based on the permission set dynamically derived from relationships and context. Because NGS-LD can explicitly describe relationships, it is conceptually easy to align with the ReBAC relationship model. However, in practical operation, a design is required to map and synchronize the NGS-LD relationship definitions for the authorization engine.

Why the Geospatial Data Interoperability Layer is the Core of City OS

LLMs probabilistically generate "most plausible answers," but they cannot independently become the "subject of decision-making" or the "subject of responsibility." The Geospatial Data Interoperability Layer in a City OS serves not just to visualize data, but to ground all information to administrative-defined "places" and "times."

1. Clarifying the Locus of Responsibility

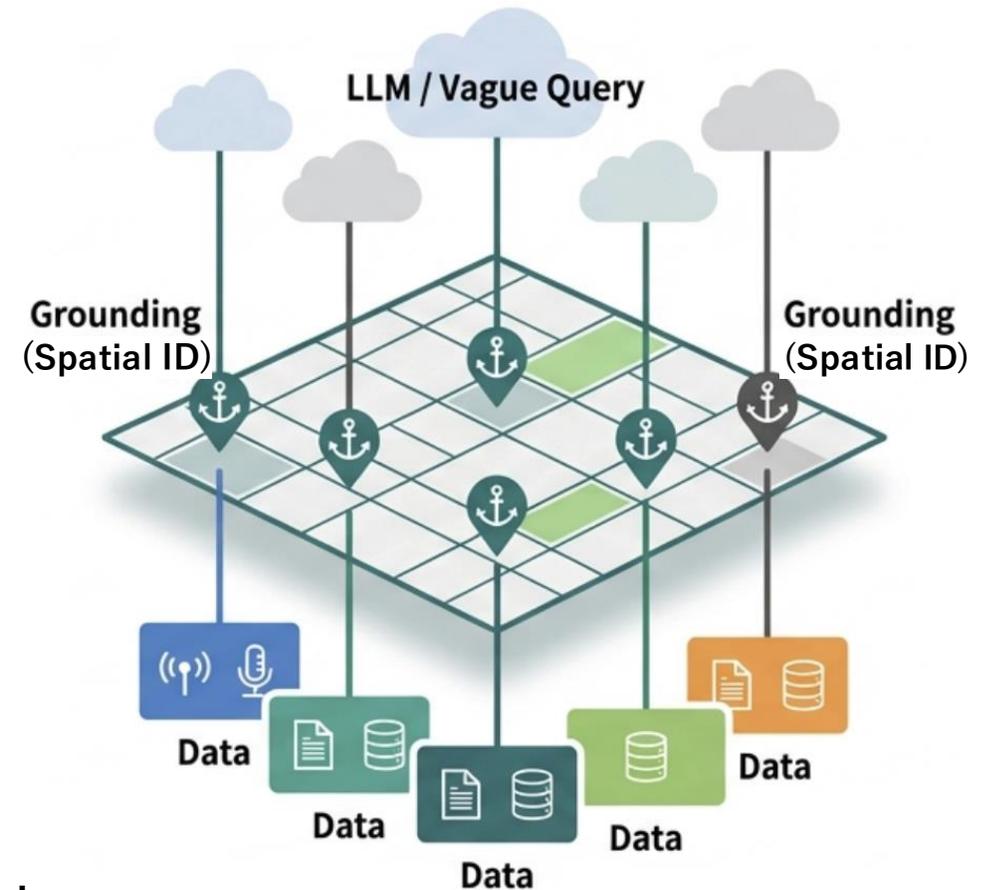
- Guaranteeing which "location" and "time" a fact belongs to through Spatial IDs and other means.

2. Interpreting Vague Queries

- Converting ambiguous human inquiries like "near that park" into precise coordinate ranges.

3. Suppressing Hallucinations

- Instead of the AI generating an answer, it refers to the "facts" on this platform to respond.



In administrative judgments that impact the real world, it is crucial that information is tied to location and time so that it can be verified.



Providing Answers by Ultimately Cross-referencing with Geospatial Data

Request:

- "User X, who is Resident A's caregiver, requests A's current location."

NGSI-LD (Meaning):

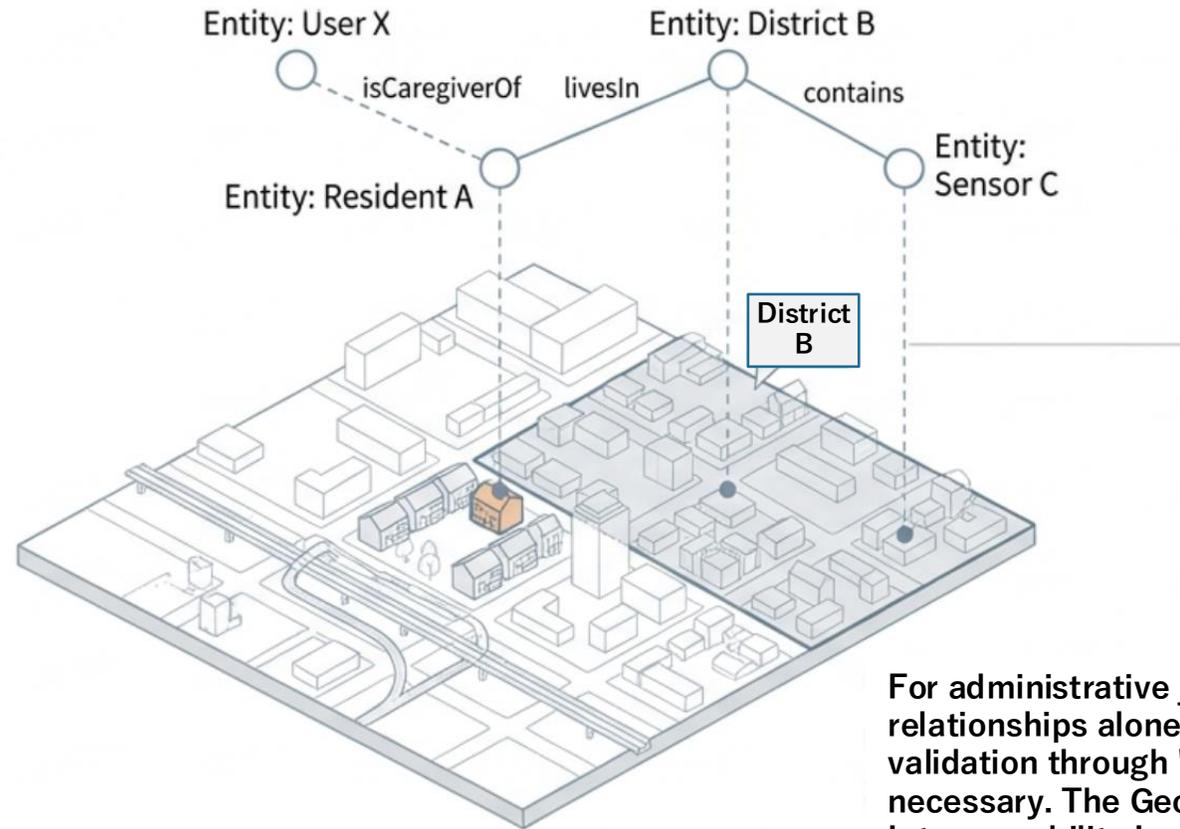
- "Resident A is a resident of District B."

Geospatial Data (Fact):

- "District B is currently an expected inundation area."
- "Resident A's GPS is currently within District B."

ReBAC (Authorization):

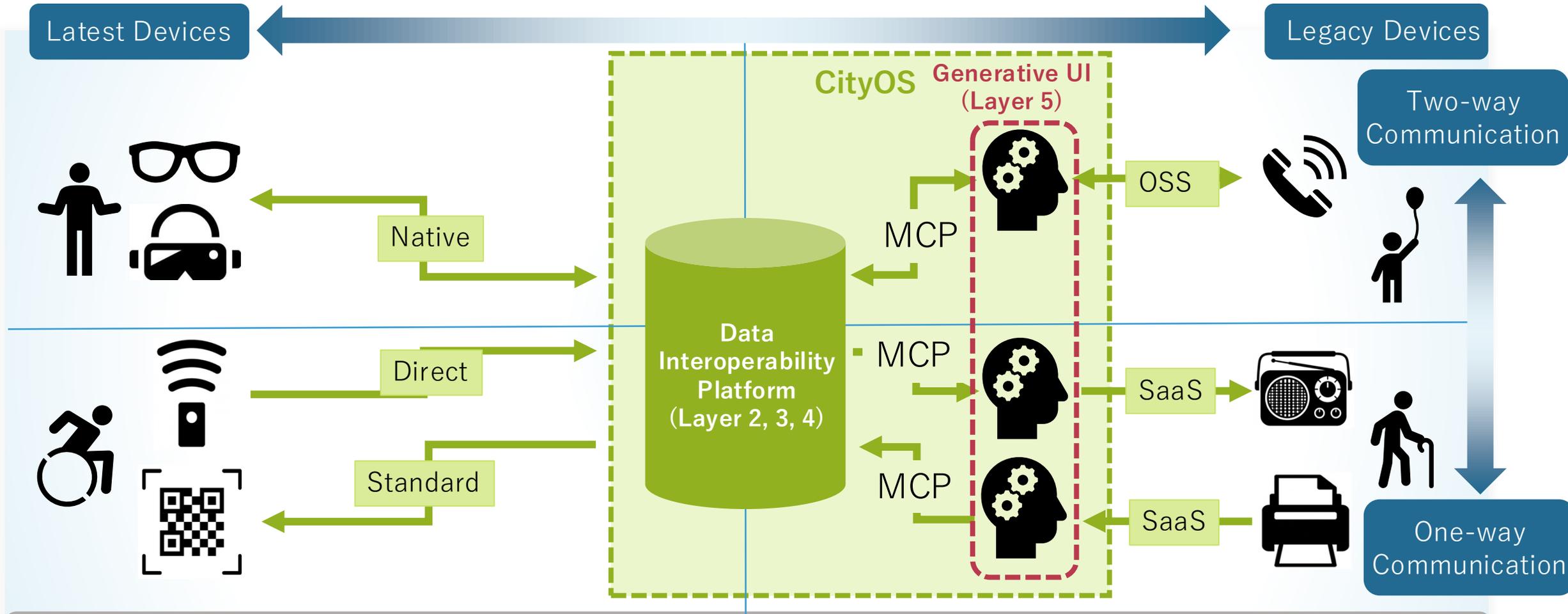
- "Therefore, provide Resident A's current location as the response."



For administrative judgments, digital relationships alone are insufficient; validation through "location" and "time" is necessary. The Geospatial Data Interoperability Layer serves as the anchor that ensures "physical authenticity" in administrative decision-making.

Analysis of User Access Methods for Smart City Services

3-1 Overview: Generative UI



Moving from an era that forces proficiency in system operation to an era where AI adapts to people. Through Generative UI and MCP technology, every touchpoint – from legacy systems to the latest devices – is integrated as an interface for the City OS.

Trends / Technical Research / Case Studies

■ Technical Research

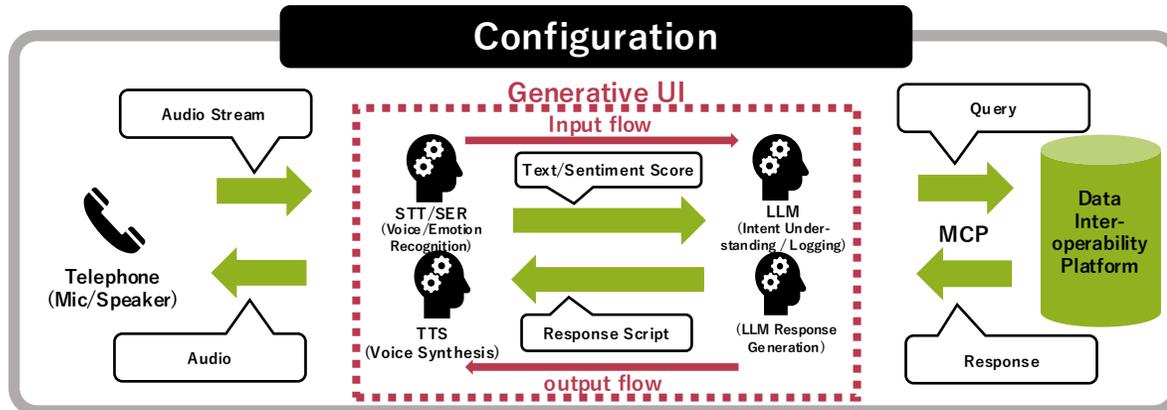
The transition from traditional IVRs that force "push-button operation" to "AI Calls" utilizing Generative AI is accelerating to achieve natural, human-like conversation where LLMs maintain context and enable flexible responses based on past dialogue.

■ Advanced Case Studies

- Japan (Rikuzentakata, Iwate): Leveraging the AI-integrated "Shin Auto-Call" system enables rapid and accurate confirmation of elderly residents' safety and evacuation status.
- South Korea: Using NAVER "CareCall," an AI with a "memory function" calls elderly people living alone, follows up on previous conversations, and has dramatically improved user acceptance.

Potential Use Cases

- **Targets** Elderly individuals who do not own a smartphone or find operation difficult; visually impaired individuals.
- **Issues to Solve**
 - Resolving Social Isolation: Providing mental care and health monitoring for the digital divide population through the "telephone handset," which has the highest affinity for them.
 - Early Intervention / Labor Shortage: Detecting abnormalities from changes in voice tone or speech intervals to optimize the allocation of human resources, such as community nurses.



Coordination / Operational Issues

■ Latency and Barge-Ins (Layer 5)

Issue: Reducing conversation stress from multi-second cloud processing delays.

Countermeasure: Adopting "Barge-in function" and low-latency Speech-to-Speech technology.

■ Escalation (Layer 4)

Issue: Safety mechanism for speakers feeling excessive stress due to confusion.

Countermeasure: Establishing operations and thresholds to forcibly switch to a human operator.

Trends / Technical Research / Case Studies

■ Technical Research

Traditional OCR was limited to fixed forms, but since 2024, combining OCR and LLM in a pipeline has become mainstream; LLMs perform semantic understanding of documents like "prescriptions" or "care records" to convert handwriting into structured data (JSON-LD) by correcting misrecognitions contextually.

■ Advanced Case Studies

- Japan: (Local governments): Drastically reduced data entry time for handwritten forms using AI inside's "DX Suite."
- USA: Categorized and indexed documents into 275 categories in two weeks with "TruAI," improving searchability and reducing audit/business costs.

Potential Use Cases

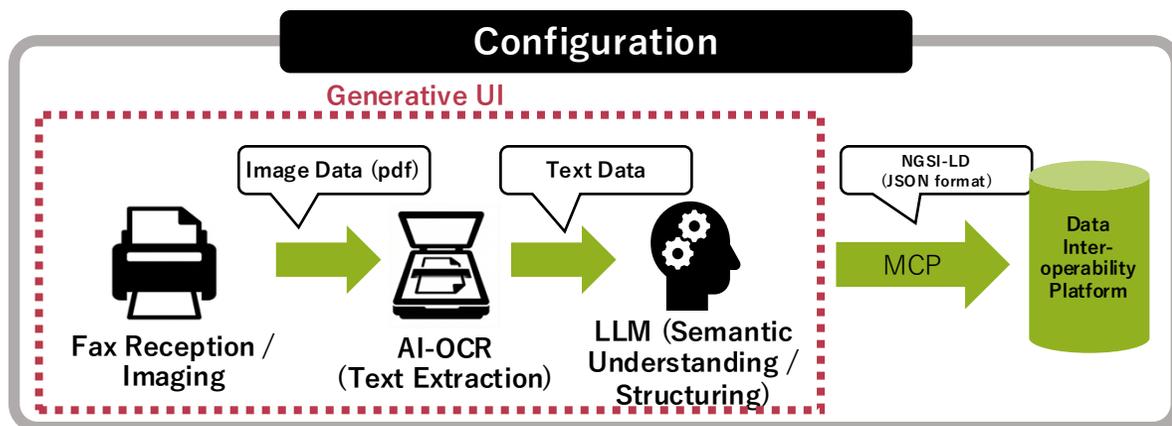
■ Targets

Government staff, medical/care workers, hearing-impaired (as telephone alternative).

■ Issues to Solve

- Inclusion of Handwriting Culture: Fully digitalizing backend operations while maintaining the reliable, simple custom of "writing with pen and paper and faxing."
- Non-standard Form Processing: Enabling database registration without human intervention even for handwritten reports with non-uniform formats.

Configuration



Coordination / Operational Issues

■ Hallucinations and Governance (Layer 4)

Issue: Risks of misreading smudged handwriting or LLM over-complementing context to generate non-existent data.

Countermeasure: Implementing a flow where AI presents its recognition accuracy and staff visually confirm only low-score sections.

■ Privacy Protection (Layer 4)

Issue: Risk of leaking unprotected personal information included in fax images.

Countermeasure: Automatically masking PII during initial AI processing before registering to City OS.

Trends / Technical Research / Case Studies

■ Technical Research

Radio is a robust information medium that remains functional even when the internet is cut off during disasters. AI can now analyze news articles, disaster prevention radio feeds, and citizen voices to automatically generate scripts for radio programs and synthesize the audio. There are also movements to deliver Japanese radio to non-native speakers by using real-time AI translation for simultaneous broadcasting in three languages.

■ Advanced Case Studies

- Japan: Conducted simultaneous radio broadcasting in three languages using real-time AI translation via the "CAMB.AI" system.
- Florida, USA: Used "BEACON" to ingest information from the state's Division of Emergency Management and implement multilingual broadcasting tailored to local demographics.

Potential Use Cases

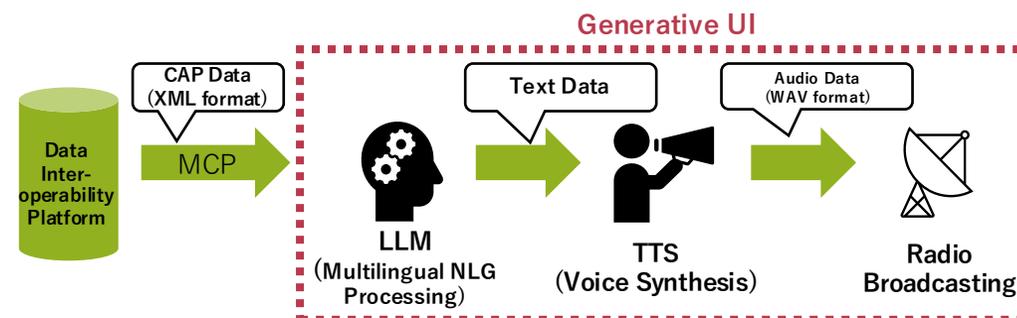
■ Targets

Foreign residents, visually impaired, disaster victims without internet access.

■ Issues to Solve

- **Multilingual Information Dissemination:** Providing real-time evacuation instructions in native languages for foreign residents who do not understand Japanese.
- **Maintaining 24-Hour Readiness:** Enabling immediate broadcasting during late-night or early-morning disasters without waiting for announcers to arrive, thereby mitigating human risk.

Configuration



Coordination / Operational Issues

■ Suppressing Erroneous Information Generation (Layer 4)

Issue: AI misinterpretations or hallucinations in disaster prevention information pose a serious risk to life.

Countermeasure: Implementing strict controls where the AI does not generate freely but rather uses CAP-format triggers to generate scripts based on fixed templates.

■ Quality Assurance of Multilingual Translation

Issue: Mistranslation of specialized terminology (e.g., evacuation site names or meteorological terms).

Countermeasure: Ensuring accuracy by maintaining region-specific proper noun dictionaries (Layer 3) and applying them to the translation engine.

3-2-4 Utilization of Latest Devices: AR Glasses ①



Trends / Technical Research / Case Studies

■ Technical Research

The AR glass market is shifting from "general-purpose gadgets" to "specialized-function models," with an expected user base of approximately 2 billion by 2025. Key trends include "lightweighting" to resemble normal glasses and the inclusion of "On-device AI" for continuous camera analysis.

■ Key Device Examples

Ray-Ban Meta: Featuring "Look and Tell" functionality to verbally describe surroundings; equipped with Meta AI, it is becoming a de facto standard for supporting the visually impaired despite being a consumer device.

Envision Glasses: Specialized for OCR; features handwriting recognition in over 60 languages, face recognition, and currency identification.

Potential Use Cases

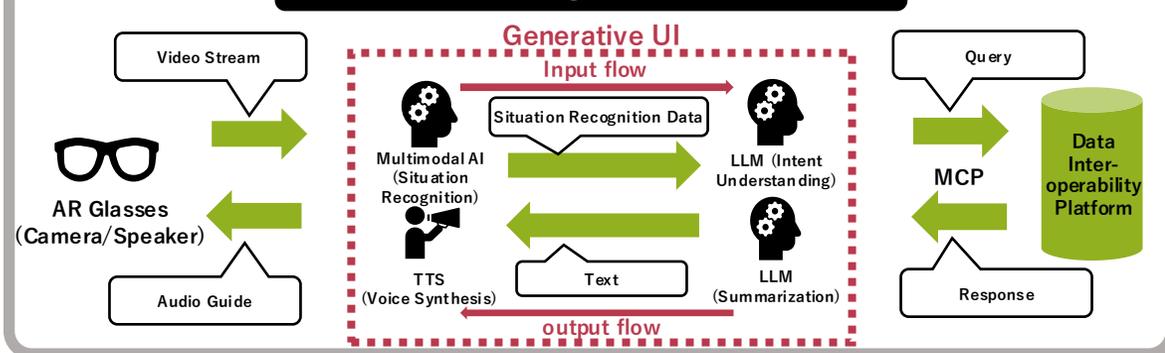
■ Targets

Visually impaired individuals, children, elderly with cognitive decline.

■ Issues to Solve

- Verbalizing Visual Information: AI assists with checking expiration dates or describing surroundings to support autonomous living.
- Autonomy in Spatial Movement: Linking with Spatial IDs to provide accurate guidance even in locations where tactile paving is missing.
- Intuitive Danger Prediction: Providing intuitive safety education by immediately notifying users of risks, such as people suddenly jumping out, through voice or warning sounds.

Configuration



Coordination / Operational Issues

■ Privacy and Social Acceptance (Layer 4)

Issue: Risks of privacy infringement due to constant camera recording in public spaces.

Countermeasure: Countermeasure: Utilizing "Edge AI" to process data on the device without sending video to the cloud and implementing LED indicators to notify others when recording.

■ Recognition Errors and Safety

Issue: Risks of AI misidentifying traffic light colors or elevation changes, potentially putting users in danger.

Countermeasure: Cross-referencing results with "High-precision 3D map data" from City OS rather than relying solely on image recognition and issuing warnings when confidence is low.

Trends / Technical Research / Case Studies

■ Technical Research

Evolution of "Live Captioning" technology; beyond simple transcription, expressive power is improving by analyzing speaker identification, emotions, and tone to dynamically vary subtitle styles.

■ Key Device Examples

- XRAI Glass: Transcribes the other person's words in real-time to display on AR glasses, while simultaneously performing multilingual translation.
- TranscribeGlass: An affordable external module that attaches to existing glasses; expected to spread among developing countries and economically constrained demographics.

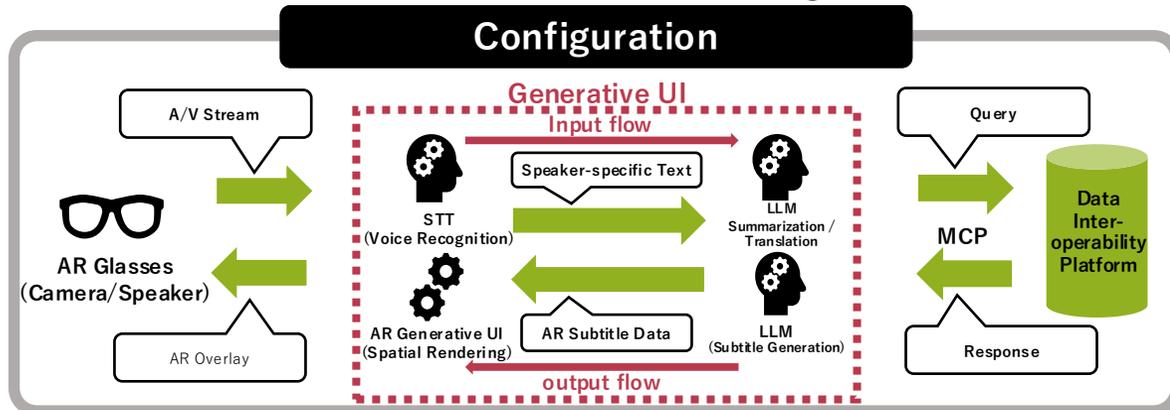
Potential Use Cases

■ Targets

Hearing impaired (hard of hearing/deaf), foreigners (language barrier).

■ Issues to Solve

- **Synchronicity in Communication:** Unlike written communication with time lags, users can understand words in real-time while looking at the other person's expressions.
- **Visualizing Multi-person Conversations:** Visually organizing "who is saying what" for hearing-impaired users for whom the "cocktail party effect" does not work.
- **Language Barrier-Free:** Real-time translation of foreign speech into native subtitles to achieve smooth dialogue.



Coordination / Operational Issues

■ Risks of "Multitasking" and UI Control (Layer 5)

Countermeasure: Constant subtitles in the field of view may distract attention from surroundings and traffic conditions.

対策: Implementing "Context-Aware UI" that detects walking via accelerometers and simplifies or turns off subtitles during movement.

■ Noise Resistance and Misrecognition Risks

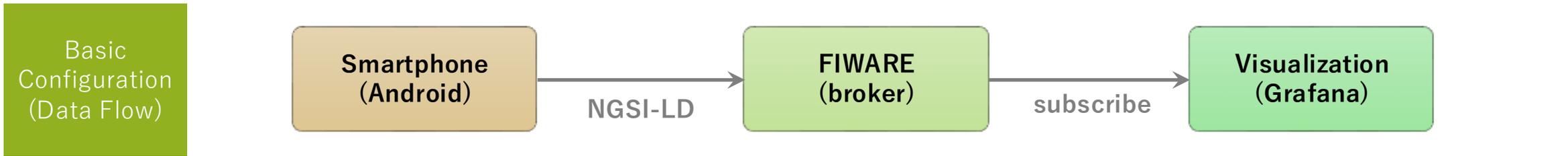
Issue: Reduced voice recognition accuracy in noisy environments or mistranslation of specialized terminology.

Countermeasure: Using directional microphones combined with "Lip-reading AI" and performing term correction via City OS dictionaries.

Analysis of Open Strategies for NGSI-LD Data Collection



Making Data Collection More Accessible via Off-the-Shelf Android Smartphones



Basic Specifications for Collection & Integration

- **Data Model Standardization:**
ETSI NGSI-LD compliant
Adopted Smart Data Models "Vehicle."
- **Separation of Concerns (Decoupled Structure)**
Subject: Vehicle / Source: Device
Dynamic linking via 'observedBy' attribute
- **Secure Integration Platform**
FIWARE (Orion-LD)
Keyrock (Authentication) + Wilma (Authorization)

Significance of This Method

- **Adoption Potential for Smaller Municipalities**
Easily promoting public transport digitalization under budget constraints
- **Interoperability via Open Standards**
Connectable to existing platforms through compatibility with NGSI-LD / GTFS-Realtime
- **Expanding Development Scope with LLMs**
Proving that individuals with AI management skills can build apps in unfamiliar domains

- P O I N T**
- 1 Implementable without specialized on-board units or hardware
 - 2 Achieves a drastic reduction in implementation costs
 - 3 Highly compatible with human-centric approaches



Practical Example with Verification App - ScraBusTracker

Conducted verification of app generation through vibe coding to confirm actual effectiveness.

Main App Specifications

- **Dynamic Binding of Vehicle ID**

Manually input Vehicle ID at startup to dynamically link device and vehicle.

Vehicle subject (+Device association).

- **High-Precision Tracking**

Acquires latitude, longitude, speed, heading, and positioning time at approx. 5-second intervals.

- **Background Execution Stability**

Continuously transmits even with screen OFF via Foreground Service.

- **NGSI-LD Payload Generation**

Real-time conversion to JSON-LD compliant with Smart Data Models "Vehicle" type.

- **Ensuring Device Traceability**

Records smartphone UUID in observedBy attribute to identify data source.

- **Implementation of Continuous Updates (Upsert)**

Logic to avoid duplication errors and keep updating latest info to Context Broker.

4-1-1 (2) Application Operational Image

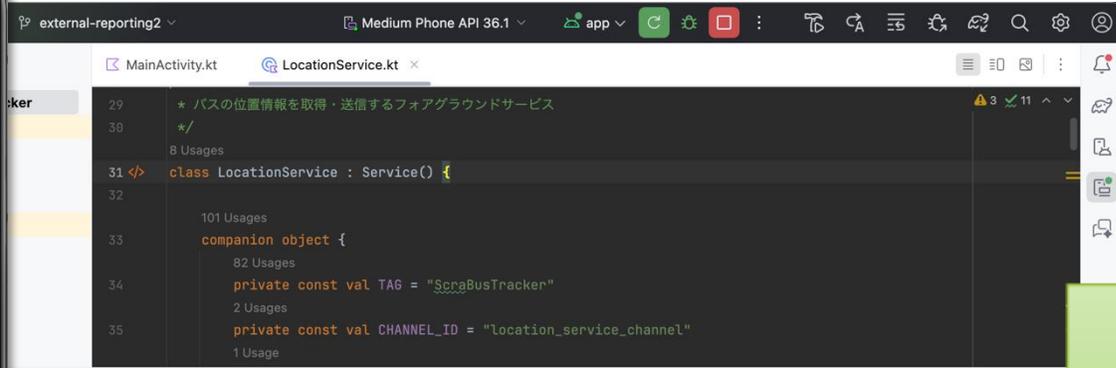


Enter Vehicle ID

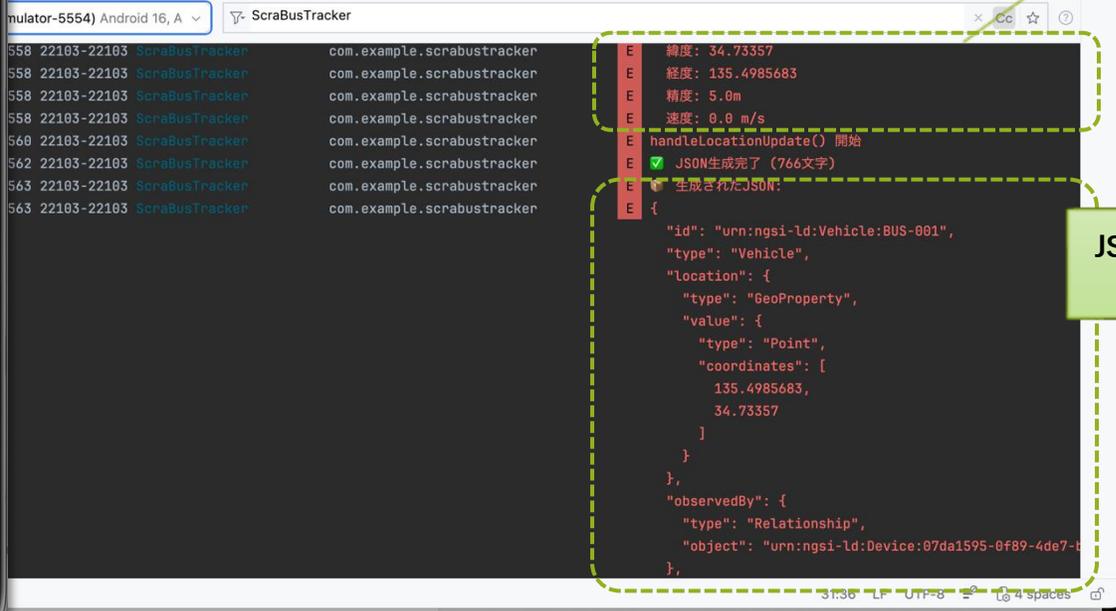
Authentication / Authorization status via Keyrock/Wilma

Measurement Start Button

Status log for operational verification



Measurement values from smartphone



JSON-LD defined in DataModel

4-1-1 (3) Time-series Data Persistence and Dashboard Visualization



Time-series data ingested into CrateDB

The screenshot shows the CrateDB console interface. At the top, it displays 'Nodes: 1' and 'System load: 2.10/ 1.46/ 0.64'. The main area is titled 'Console' and contains a text input field for SQL queries. Below the input field are several checkboxes: 'Format results' (checked), 'Store console history persistently' (checked), 'Show error trace' (unchecked), and 'Clear History'. The SQL query entered is:

```
SELECT *  
FROM etvehicle  
ORDER BY time_index DESC  
LIMIT 10;
```

 Below the query, a status message reads 'SELECT OK, 10 records returned (0.086 seconds)'. The results are displayed in a table with the following columns: entity_id, entity_type, time_index, fiware_servicepath, and _original_. The table contains four rows of data, all with entity_type 'Vehicle' and _original_ 'NULL'. A dashed green box highlights the table content.

entity_id	entity_type	time_index	fiware_servicepath	_original_
urn:ngsi-ld:Vehicle:BUS-001	Vehicle	1770939829768 (2026-02-12T23:43:49.768Z)	/	NULL
urn:ngsi-ld:Vehicle:BUS-001	Vehicle	1770939811487 (2026-02-12T23:43:31.487Z)	/	NULL
urn:ngsi-ld:Vehicle:BUS-001	Vehicle	1770939796246 (2026-02-12T23:43:16.246Z)	/	NULL
urn:ngsi-ld:Vehicle:BUS-001	Vehicle	1770939782374 (2026-02-12T23:43:02.374Z)	/	NULL

The screenshot shows a Grafana dashboard for 'ScraBusTracker'. The top navigation bar includes 'Home > Dashboards > ScraBusTracker' and buttons for 'Edit', 'Export', and 'Share'. Below the navigation, there are controls for 'Previous month', a search icon, and a 'Refresh 5s' button. The main content area is divided into two panels. The top panel, titled 'MapView', displays a map of Japan with several green location markers. A green callout box points to the map with the text 'Plotting location info on dashboard'. The bottom panel, titled 'New panel', shows a time-series plot with a y-axis from 0 to 1 and an x-axis from 01/01 to 01/31. A single data point is plotted at approximately 01/18 with a value of 1.0. The legend indicates the data series is 'speed'.

Plotting location info on dashboard

Verified Issues and Concerns for Social Implementation



Knowledge Gained from Verification

- **Android HTTP Communication Constraints**

Resolved issues where CLEARTEXT communication was blocked by using the usesCleartextTraffic setting.

- **JSON Escape Processing**

Solved backslash escape issues when sending @context URLs in Android environments through string replacement.



Future Challenges (1)

- **Accuracy Differences Based on Device/OS**

Variation in positioning data occurs due to chip performance and power-saving settings.

- **Impact of Communication Environment**

Risks of data loss and transmission delays in maritime, mountainous, or urban canyon areas.

- **Noise During Cell Handoffs**

"Position jumping" phenomenon during base station switching while moving at high speeds.



Future Challenges (2)

- **Battery Consumption Load:**

Heavy drain due to constant GPS operation; continuous power supply equipment on the vehicle side is essential.

- **Thermal Resistance**

Concerns about thermal runaway or shortened hardware lifespan due to dashboard placement in summer.

- **Background Constraints**

Stricter restrictions on background transmission following OS updates.

- **Authentication Credential Management**

Importance of concealing IDs, Secrets, etc., in environments co-existing with other apps.



Ensuring Openness Based on the FIWARE Stack

Configuration using a PEP Proxy instead of direct Broker exposure to achieve policy-based access control and Zero Trust.

Standard Authentication Flow

- **Utilization of OAuth2 Password Grant**
Token acquisition via username/password

- **Adoption of Bearer Token Method**
Continuous authentication via X-Auth-Token header

- **Authentication and Authorization**
Authentication: Keyrock (OAuth2.0 token issuance)
Authorization: Wilma (PEP Proxy) for policy-based access control and Zero Trust

- **Server Configuration**
Keyrock 7.9.0(MariaDB 10.4) Wilma 7.9.0
Orion 3.8.0(MongoDB 4.4)

Zero Trust Access Control

- **Interception by Wilma (PEP Proxy)**
Real-time authorization inquiries to Keyrock

- **Principle of Least Privilege**
Recommending access permission for specific IDs and paths only

Client Implementation

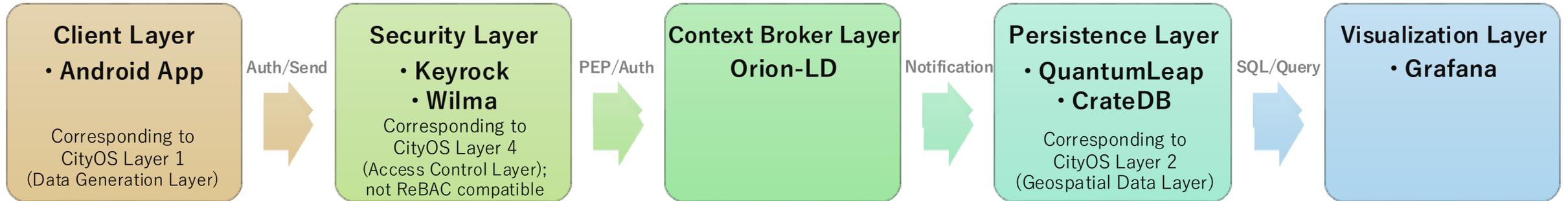
- **Token Expiration Management**
Implementation of automatic refresh upon 401 errors.

- **Secure HTTPS Communication**
Use of standard libraries such as OkHttp3

*Note: Configured via OAuth2.0 Password Grant (not API key) to utilize Keyrock and Wilma.



System Layer Architecture



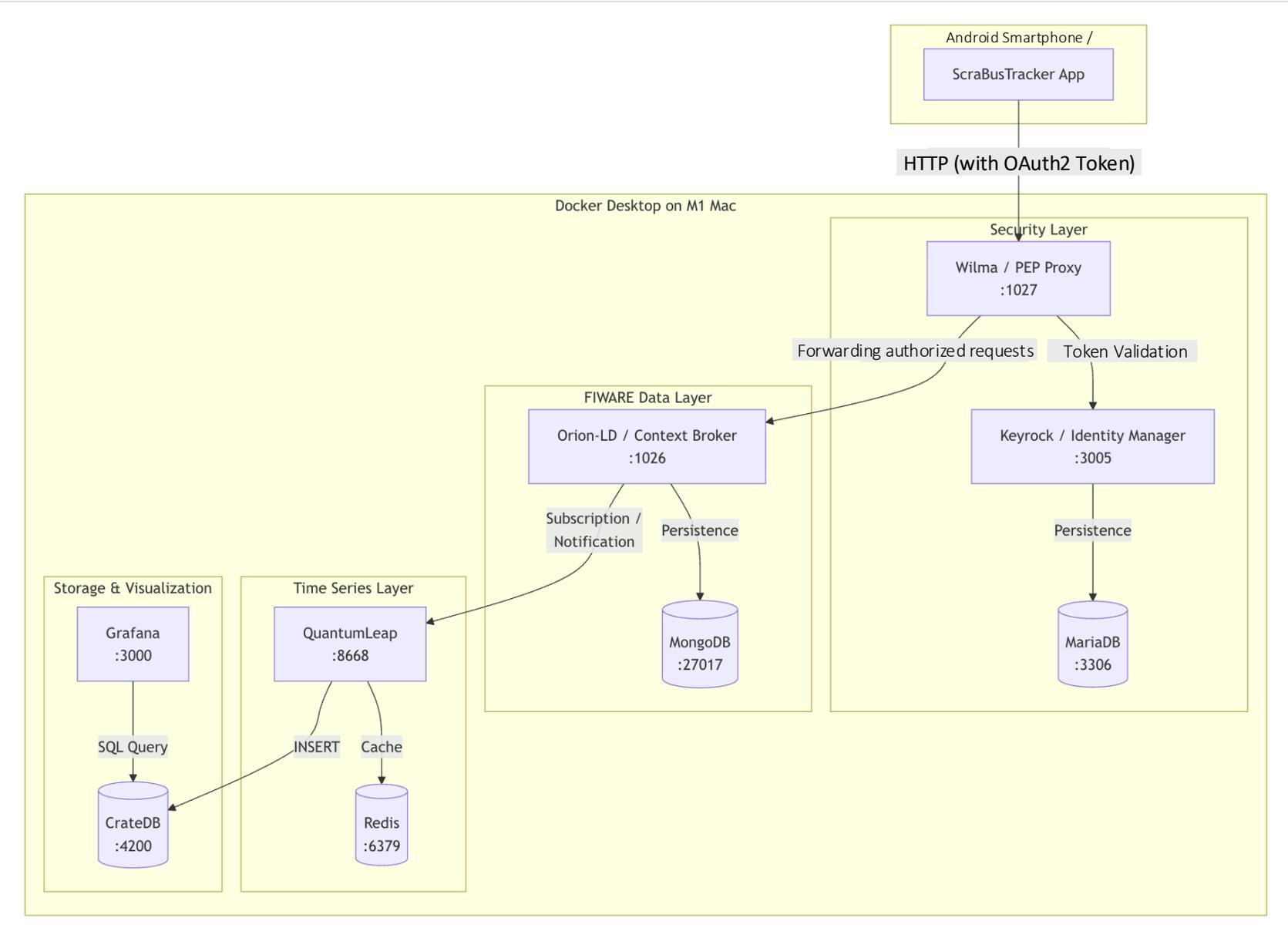
Standardized Data Flow

1. **Authentication:** Acquire access token from Keyrock
2. **Transmission:** Upsert data to Orion-LD via Wilma
3. **Notification:** Orion-LD notifies QuantumLeap of changes
4. **Persistence:** QuantumLeap stores data in CrateDB
5. **Visualization:** Grafana references CrateDB and updates display

Technical Features / Details

- **Semantic Integration:** Data semantic definition utilizing @context
- **Stability:** Avoiding continuous transmission errors through Upsert processing
- **M1 Mac Optimization:** Container operation via Rosetta 2 (Linux/AMD64) for ARM architecture compatibility.

4-2-1 Recommended Architecture Configuration



Adding Context via Vehicle Subject + Device Reference

Ensuring device fluidity, GTFS compatibility, and data quality simultaneously through a decoupled model with Vehicle as the subject and Device as the reference.

Model Design Policy

● Adopted Smart Data Models "Vehicle":

Standard entity in the ETSI-compliant Transportation domain

● Device Model Not Adopted:

Since bus drivers carry devices around, setting Device = Vehicle would lead to accumulation of incorrect data

● Vehicle Subject / Device Reference Model:

Based on the principle of Separation of Concerns, Vehicle is the data subject and Device is the reference

- **Vehicle ID remains invariant even if the device is used for a different bus.**
- **1:1 mapping with GTFS-Realtime is possible.**
- **Ensures interoperability with existing transportation data platforms.**

Operational Example

Set the (boarded) vehicle number to be measured by the ScraBusTracker app



Vehicle number is fixed

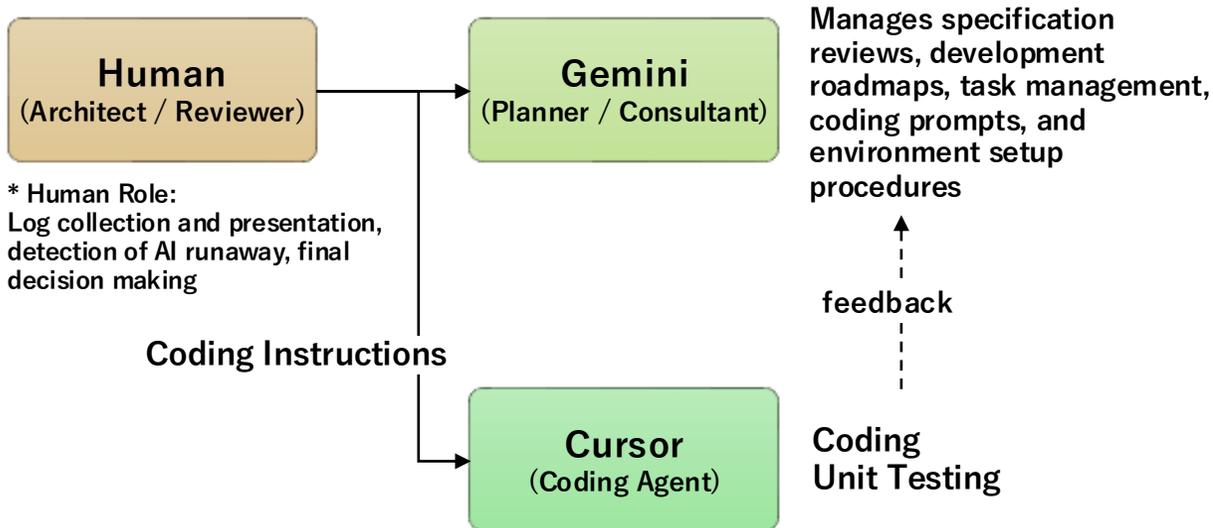
Devices are fluid

Data quality is ensured because the reference source is clear while maintaining consistency as a standalone data unit.



"Coding" skills can be delegated to AI, but humans need the skill to manage the AI.

Implemented AI Agent Configuration and Workflow



Situations Requiring Engineering Knowledge

- Resolving Errors and Bugs**
 Selecting logs/materials and narrowing down discussion points. Specialized vocabulary is needed to explain UI operations to the AI
- Struggling with Fixes**
 AI tends to become short-sighted (digging too deep into details) as turn counts increase. Humans must switch the perspective for investigation and isolation based on AI characteristics and IT literacy

AI Management Literacy	Log-driven development mindset, prompt operational skills, and maintaining instruction consistency
Verified Potential	System construction is possible in inexperienced domains if appropriate information is provided to the AI

*Note: Human judgment is indispensable in infrastructure domains.



Time-Series Data Management in Digital Twin Architecture

Intent Behind Defining Time-Series Data Handling

Technical containment of hallucination and providing context understandable by the LLM

Technical Containment of Hallucinations

The primary intent is to eliminate the risk of the LLM performing incorrect operations or interpretations on the database.



Avoiding Risks in SQL Generation

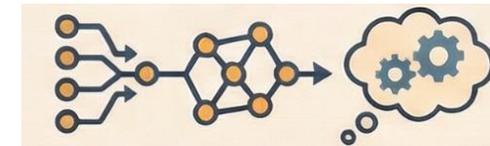
Configurations where an LLM autonomously generates complex SQL queries to directly manipulate a database are prone to structural errors and data fabrication, and are judged to have a "high hallucination risk."

Setting up Guardrails

Instead of allowing the LLM to touch the raw DB, the data infrastructure acts as a "guardrail" by allowing data access only in a predefined safe format (fixed schema) via an API (QuantumLeap).

Providing Context Understandable by LLM

By linking NGS-LD and time-series data, the state of the city is communicated to the LLM as semantic knowledge.



Providing "Structured Meaning" instead of "Numerical Values"

The intent is to convert data from "mere sequences of numbers" into "meaningful information" so that the LLM can correctly explain city conditions to humans.

Fixing Evidence as "Facts"

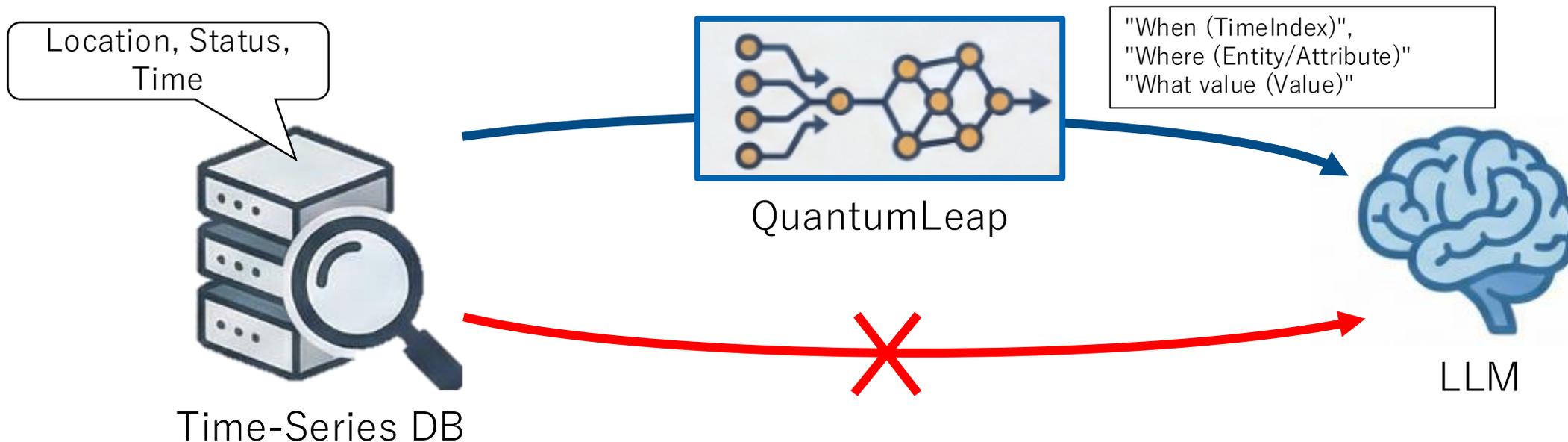
This is to make time-series data function as the "external brain" of the City OS and ground the AI's responses in reality.

- **Fixing Facts via "Fixed Schema"**

QuantumLeap handles data not as a mere sequence of numbers, but through a fixed schema based on NGSi.

- **Ensuring Safety and Freshness of Data Reference**

When the LLM refers to past history or trends, QuantumLeap serves as the gateway that guarantees the "correctness" and "freshness" of that information.





CrateDB

A distributed database with the flexibility and scalability of **Elasticsearch** and compatibility with **PostgreSQL**

Features

- **Hybrid Structure**
Combines the convenience of SQL with the scalability of NoSQL (Elasticsearch-based)
- **Near-Schema-less Flexibility**
Not only relational data (table format), but nested JSON objects can be stored as-is, allowing for high-speed search and aggregation on the content
- **Distributed Architecture**
Based on Elasticsearch technology, it can scale up horizontally simply by adding nodes

TimescaleDB

A database optimized for time-series data based on pure **PostgreSQL**

Features

- **Powerful Data Compression**
Proprietary compression algorithms can reduce storage capacity by up to 90% or more. High-speed queries are possible even in a compressed state.
- **Continuous Aggregates**
Automatically calculates metrics like "1-minute averages" or "1-hour totals" in the background and maintains them as views. Dramatically speeds up dashboard displays
- **Full PostgreSQL Functionality**
The entire PostgreSQL ecosystem is available as-is, including PostGIS (geospatial), JSONB (schema-less), full-text search, foreign key constraints, JOIN, etc.

5-4 Comparison of DBs based on LLM Integration



Evaluation Axis	CrateDB		TimescaleDB		Selection Criteria for LLM Integration
	Rating (◎○○△×)	Comment	Rating (◎○○△×)	Comment	
Safety of LLM Integration (Hallucination Suppression)	◎	Highest compatibility with QuantumLeap API. Reliable data provision via Fixed Schema (NGSI).	○	Possible via QuantumLeap, but for advanced analysis, it tends to connect directly to the DB (SQL), increasing the risk of LLM fabrication.	CrateDB if emphasizing guardrail operations via API (QuantumLeap).
Search & Aggregation Performance	◎	High-speed geospatial queries and distributed parallel processing for massive data.	○	Strong in single-node writes and analysis involving complex JOINS.	CrateDB for wide-area/massive device geospatial searches in Smart Cities.
Operations & Maintenance (O&M)	△~○	Scaling is easy, but proprietary operational knowledge (shard management, etc.) is required. Securing engineers is a challenge.	◎	PostgreSQL knowledge and tools can be reused as-is. Easier to secure talent for backup and maintenance.	TimescaleDB if emphasizing existing Postgres operational assets or continuity of human resources.
Storage Efficiency	○	Standard compression.	◎	Boasts extremely high compression ratios, significantly reducing disk costs.	TimescaleDB if emphasizing long-term data storage costs.
Future Scalability	◎	Horizontal distribution via adding nodes is easy. Strong for city-scale expansion.	○	Vertical scaling is the base. Horizontal distribution is possible but the configuration becomes complex.	CrateDB if the number of devices is planned to increase exponentially.

Recommended Configuration for LLM Integration

Prioritizing AI Safety and Hallucination Suppression

**[Configuration] QuantumLeap + CrateDB:
The most recommended combination for the standard City OS architecture.**

Reasons for Selection

- **Compatibility with QuantumLeap**
As the default configuration, it offers the most robust support and the longest proven track record
- **Strength in Geospatial Queries**
Superior performance in searches combining "Location" and "Time"—critical for Smart Cities—and distributed parallel processing
- **Scalability**
Employs a horizontal distributed model that scales performance by adding nodes, flexibly accommodating city-scale device growth

TimescaleDB depends on future support

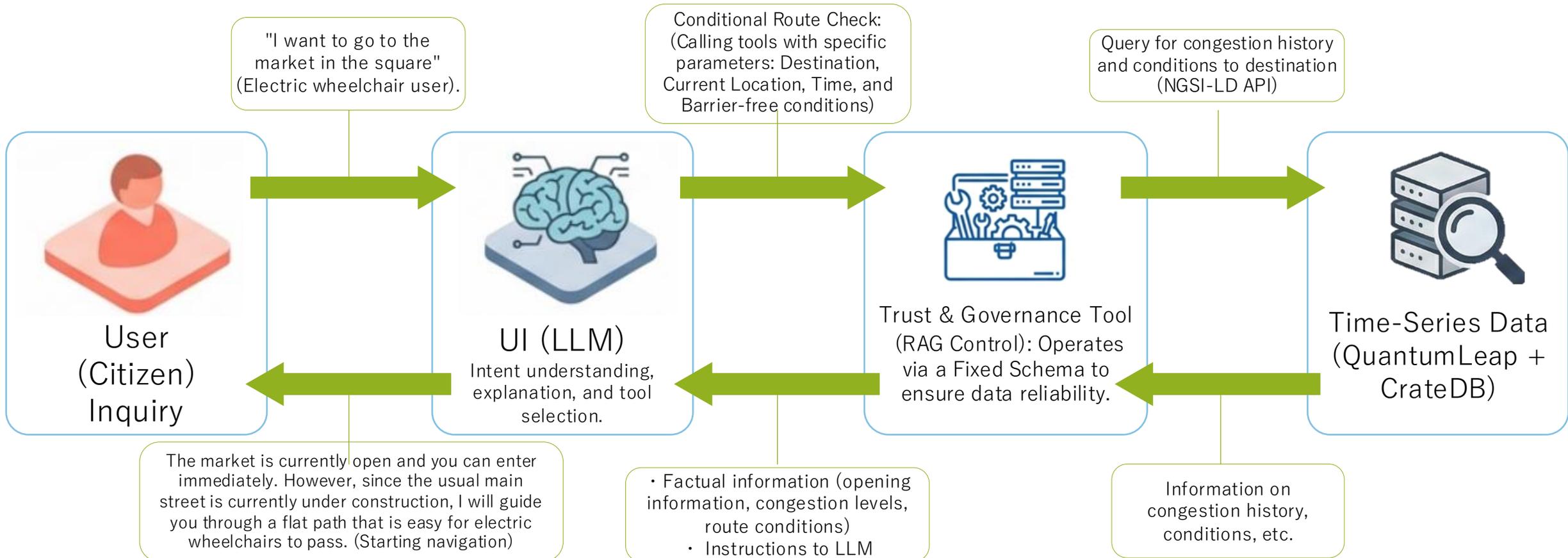
- As QuantumLeap support matures, use cases may emerge where TimescaleDB is prioritized due to its complex aggregation / analysis capabilities and operational maintainability.
- Key drivers include advanced data analysis needs and reducing operational costs for large-scale data via high compression ratios.

5-6 Image of Time-Series Data Utilization



In a configuration using **QuantumLeap + CrateDB**, this illustrates the data flow when an electric wheelchair user says, "I want to go to the market in the square."

Time-series data maintains historical information – such as congestion levels in the area between the current location and destination, electric wheelchair telemetry, elevator operation status, and construction logs—and serves the role of conveying these as "facts" to the **LLM**.





Expert Opinions

Experts who provided advice for this project

Name	Affiliation
Fumihiko Nakamura	Project Professor, Graduate School of Frontier Sciences, The University of Tokyo
Takehiko Nagumo	Representative Director, Smart City Institute Japan
Takuro Yonezawa	Associate Professor, Graduate School of Engineering, Nagoya University (Information and Communication Engineering)

Regarding this revision, we received many forward-looking opinions from experts. From a technical standpoint, the direction aligns with international standards and social trends; however, there is also the view that further development incorporating economic rationality will be necessary going forward.

In other words, at the current stage, this represents a first phase with a strong “smart government” emphasis*¹, serving as a guidepost from the public sector. To further promote innovation, it will be necessary to revitalize activities centered on private-sector-led economic activity. To that end, it may also be worth considering initiatives combined with regulatory reform, similar to what was envisioned under the Super City concept.

Meanwhile, from the perspective of urban development, much of the data that is fundamentally needed remains insufficient*². By visualizing data through a geospatial data integration platform, generalizing simplified data acquisition through vibe coding, and storing data in a way that prevents AI from generating recognition discrepancies, it will become possible, for example, to obtain at low cost the data necessary to simulate economic revitalization measures such as setting pedestrian-only street hours. Furthermore, in utilizing such data, employing an analysis platform mediated by LLMs would significantly expand the scope of what a single staff member can understand and evaluate.

Moreover, as such micro-level data becomes available, it will become possible to understand “regional bias”*³ and thereby facilitate consideration of directions suited to the specific locality. Discussions will continue regarding whether to address this through RAG or by building a locally sovereign AI system. However, as a first step, it is important to properly assemble regional data in a form that can be clearly understood.

—
*¹ Comment by Mr. Nagumo

*² Comment by Mr. Nakamura

*³ Comment by Mr. Yonezawa