Cross-ministerial Strategic Innovation Promotion Program(SIP)3rd Period /
Building a Smart Mobility Platform /

Construction of a Digital Twin for mobility society experiments incorporating diverse geographical spatial information and Nationwide Pseudo-People-Flow data

FY2024 Annual Report

Center of Spatial Information Science at University of Tokyo (CSIS)
Association for Promotion of Infrastructure Geospatial Information Distribution(AIGID)
Softbank Corp.
CTI Engineering Co.,Ltd.

Content

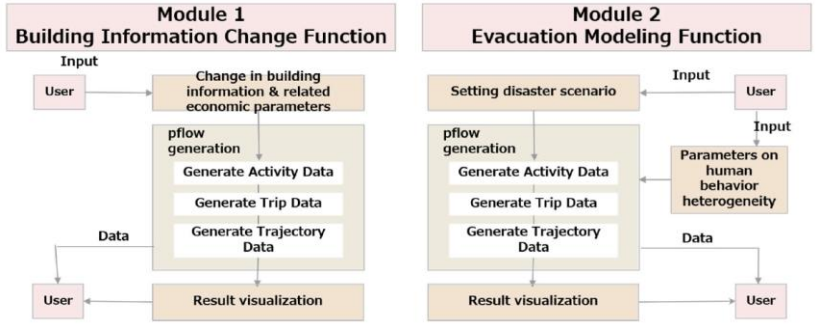
Overview

Overview

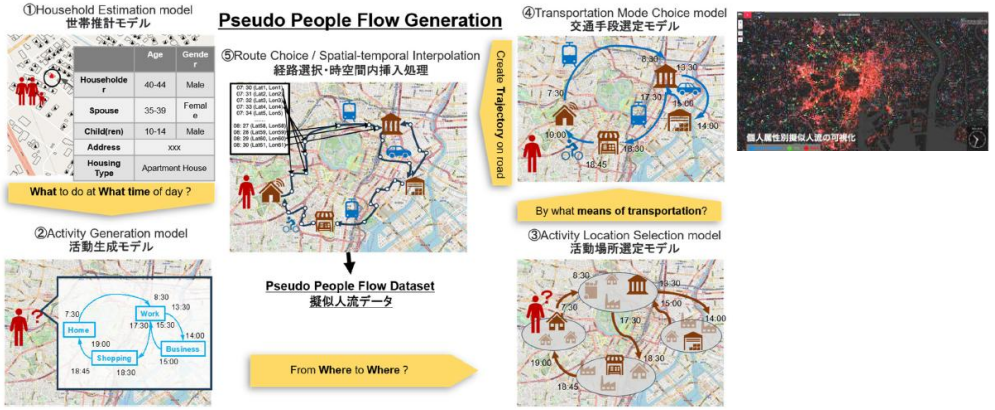
①Development Objectives			• Hypothesis testing and impact evaluation of behavioral changes resulting from social experiments • Deployment as an explanatory tool for the general public		
②Purpose			Focusing on the newly redefined mobility and vibrant urban development, there is a growing demand to realize a "safe, comfortable, rich, and lively new form of mobility" where pedestrians, micro-mobility, various vehicles, and public transport smoothly mix and coexist. To efficiently and effectively plan this, and to facilitate consensus-building among stakeholders and streamline administrative processes, the goal is to establish a "Digital Sandbox" system. This system will embody street spaces, incorporating diverse geospatial information, nationwide pseudo-people-flow data, vehicles and other mobility forms, as well as virtual spaces, and simulate them in the digital space.		
③Implementation Structure			Center of Spatial Information Science at University of Tokyo (CSIS), Association for Promotion of Infrastructure Geospatial Information Distribution（AIGID）, Softbank Corp., CTI Engineering Co.,Ltd.		
④Work schedule			Year 1: Organize examples of social experiments and discuss system requirements Year 2: Develop the prototype Year 3: Apply to 3 social experiment cases Year 4: Apply to 6 social experiment cases (cumulative) Year 5: Apply to 10 social experiment cases (cumulative)		
⑤Progress Status			FY2023: Organized 257 social experiment cases and discussed system requirements FY2024: Established research workshops and currently building the prototype		
⑥Exit Strategy	**The party responsible for Social implementation**	**At the End of SIP**	Center of Spatial Information Science at University of Tokyo (CSIS), Association for Promotion of Infrastructure Geospatial Information Distribution（AIGID）, Softbank Corp., CTI Engineering Co.,Ltd.	**At the Time of Social Experiment**	Association for Promotion of Infrastructure Geospatial Information Distribution（AIGID）
	Provided Resources※		Digital city services and associated simulation services (approximately 10 social experiment cases).		Digital City Services and Associated Simulation Services (Expansion of the Number of Cases)
	Target Users		Municipalities belonging to the research workshops (for trial implementation).		Municipalities (Full Implementation) Municipalities will fully implement the services, integrating them into their operations.
	Convenience and Value Provided to Users		Users can perform mobility simulations in digital space without making significant investments, allowing for hypothesis testing and impact evaluation.		Traditionally, when examining policies, significant investments were required to conduct real-world social experiments in order to verify their effectiveness and impact. However, it is now possible to conduct simulations in a digital space, allowing for hypothesis testing and impact evaluation without the need for such substantial investments.

Structure of the Research and Development

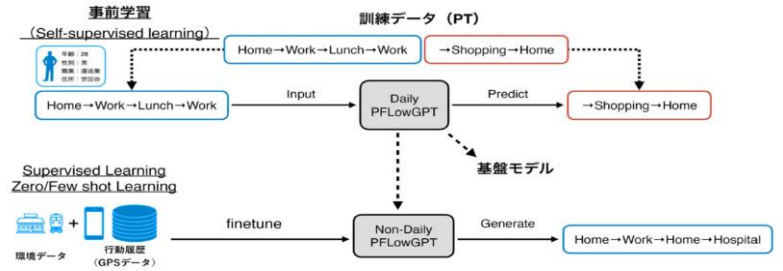
（1） Categorization of Mobility Simulations and Design of Digital Sandbox Platform



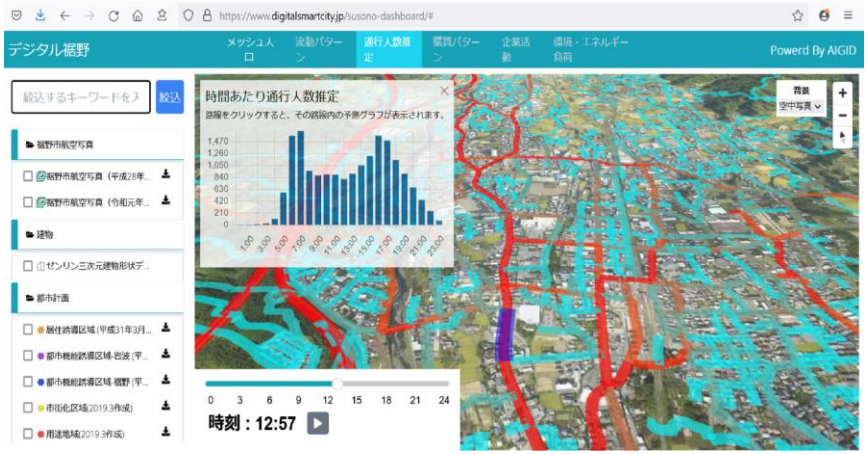
（2） Construction of Simulation Elements for Various Cases and Acceleration of Pseudo-People-Flow Generation Processing



（3） Enhancement of Accuracy and Quantification of Uncertainty in Pseudo-People-Flow Models through the Integration of Fragmented real Human Mobility data



（4）Implementation of the Digital Sandbox Platform and its application to social experiments, as well as the creation of user communities



Work schedule

	2023	2024	2025	2026	2027
モビリティシミュレーションの類型化とデジタルサンドボックス基盤の設計	類型化と設計	タイプの追加・設計改良			
各ケースのシミュレーション要素の構築と擬似人流生成処理の高速化	設計	実装	要素の追加・改良	高速化や入出力の多様化	
断片的な実人流を組み合わせた擬似人流モデルの高精度化と不確実性の定量化	生成型モデルの構築	実人流による高精度化	不確実性の定量化	推定モデルの改良・高精度化・高速化	
デジタルサンドボックス基盤の実装と社会実験への適用	プロトタイプ設計	プロトタイプ実装	試験利用改良	複数の社会実験等で利用・適宜改良	

Prototyping of a Mobility Digital Twin

Simulation Elements for Various Cases

Positioning of This System

- There are existing transportation simulation packages and dispatch management services for buses and taxis. However, the former requires specialized knowledge and extensive data preparation, while the latter comes at a considerable cost and can only be used once a budget is secured.
- This system focuses on enabling municipalities and practitioners to perform simulations using only a Web UI (no coding required), with results available quickly (within a few minutes).
- While the system concentrates on a set of typical use cases, it also aims to gradually expand customization features to some extent. However, non-standard or irregular tasks are envisioned as optional commissioned services.

	Transportation Simulation Packages	Taxi/Bus Dispatch Management Services	This System
Function ality / Usability	Offers many features, but requires high expertise. Also needs preparation of data and programming, resulting in a high barrier for general users.	Easy to use as it is tailored for specific purposes.	Focuses on a few typical use cases. Simple Web UI enables results within minutes. Includes customizable features and continues to improve.
Cost	Some are open-source.	Often expensive.	Aims to be low-cost and subscription-based, usable by municipalities nationwide.

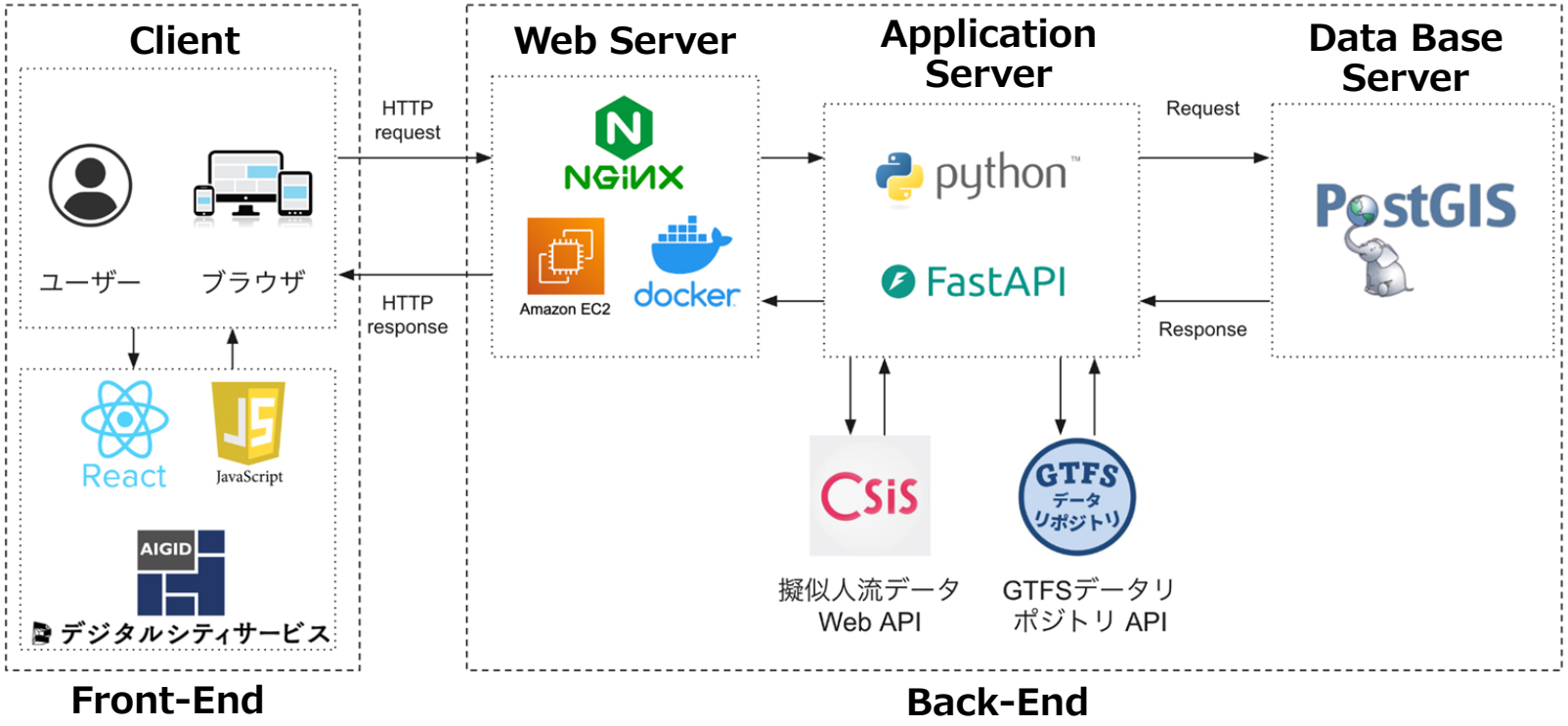
Use Case Scenarios Overview

- Demonstration Scenarios (5 Typical Patterns) and Processing Flow

①Scenario Selection	②Parameter setting	③formation process	④Data output and visualization
a. Forecast number of public transportation users Estimation of user increase due to enhanced public transport services	The user selects public transport GTFS data and configures increased service frequency	Re-select the mode of transportation from Pseudo-People-Flow trip data using a spatio-temporal interpolation service	The total number of users before and after the simulation, as well as the number of users at each bus stop, is output
b. Implementation of on-demand transportation Introduction of on-demand transport in response to public transport reductions	The user specifies the area for service reduction and inputs parameters for on-demand transport	Calculate demand based on the trip data from the Pseudo-People-Flow	Fare comparison results between public transport and on-demand transport are output, and on-demand demand is visualized on a background map
c. Estimates of visitors to specific areas Visitor estimation resulting from events held in specific areas	The user designates the event area and enters event-related parameters	Future enhancement: Use a visitor estimation model built from GPS data together with Pseudo-People-Flow activity data	Total visitors with and without the event and time-segmented inflow results are displayed, along with a map-based visualization of origin distribution
d. Flow changes due to redevelopment Changes in surrounding flow due to the construction of large shopping centers or redevelopment of shopping districts	The user selects the redevelopment area and inputs development parameters	Re-select destinations based on Pseudo-People-Flow activity data	Mobility change results are output and visualized on a background map within the tool
e. Flow impact of tourism promotion Changes in tourism flow caused by strengthened dissemination of event information	The user designates both the event and promotion areas and enters parameters for event and promotional reach	Re-select destinations based on Pseudo-People-Flow activity data	Mobility change results are output and visualized on a background map within the tool

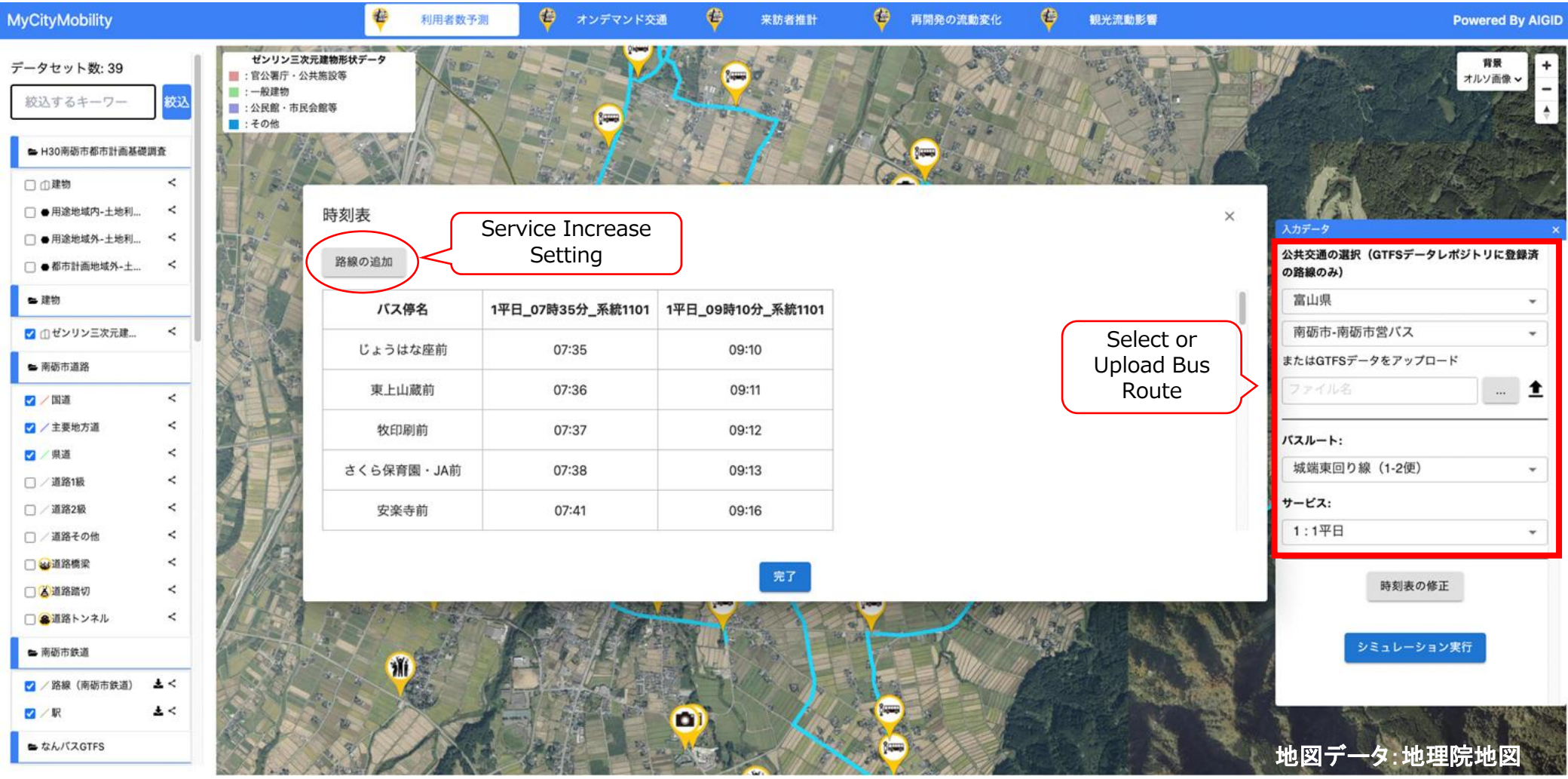
System Configuration Diagram (Server)

- The frontend system, including digital maps, is built upon the Digital City Service platform, with input/output user interfaces developed using React and JavaScript.
- On the backend, key data sources include:GTFS data, which is retrieved via the GTFS Data Repository API, Pseudo people flow data, obtained and utilized from the "Human Flow Project" of CSIS, the University of Tokyo.



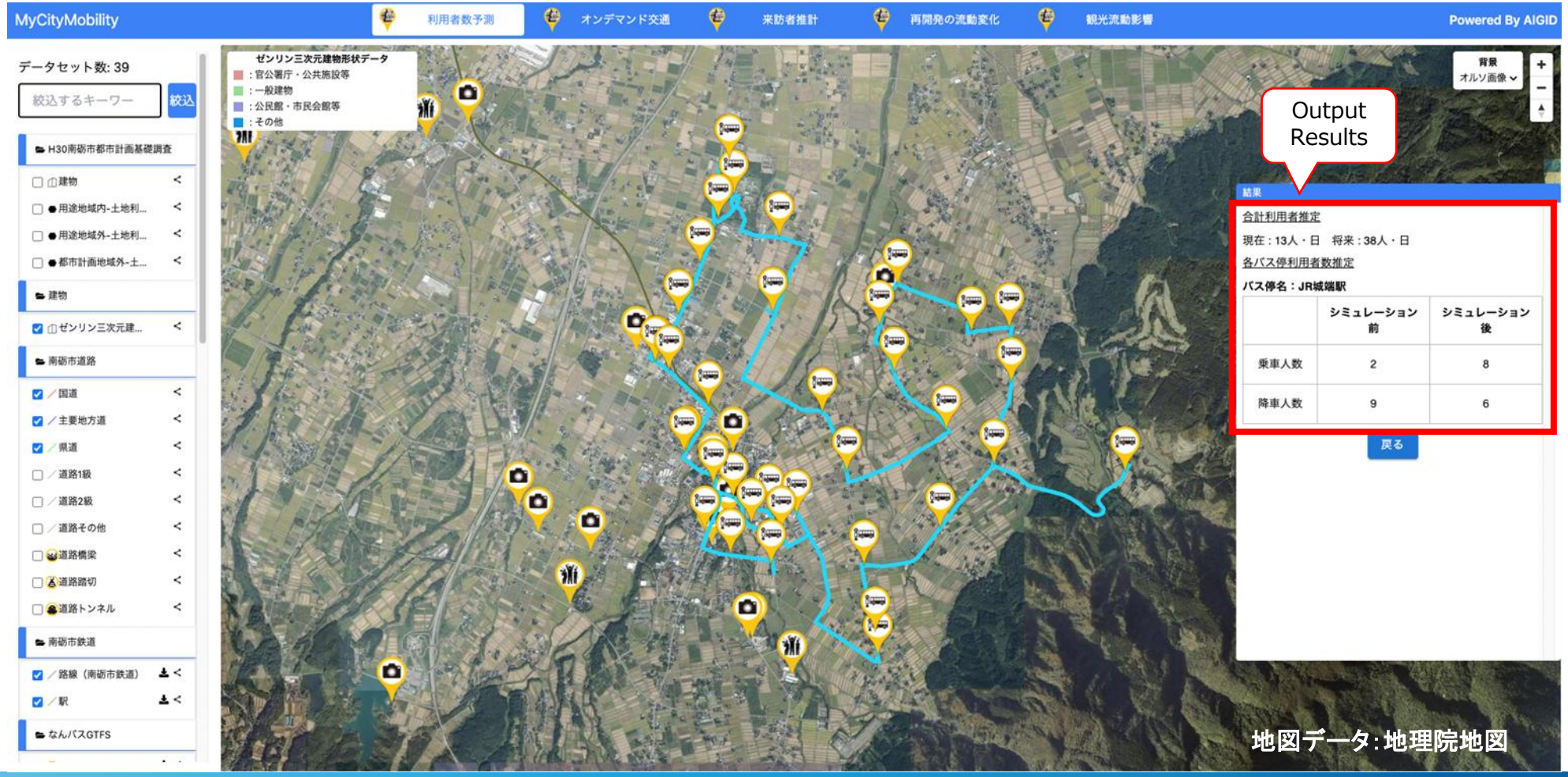
a) Forecast of public transportation users (Input)

- Users can choose or upload public transport bus routes and add additional schedules.



a) Forecast of public transportation users (Output)

- Outputs include total ridership before and after simulation and user counts per bus stop.
- Nationwide coverage is planned within this fiscal year.

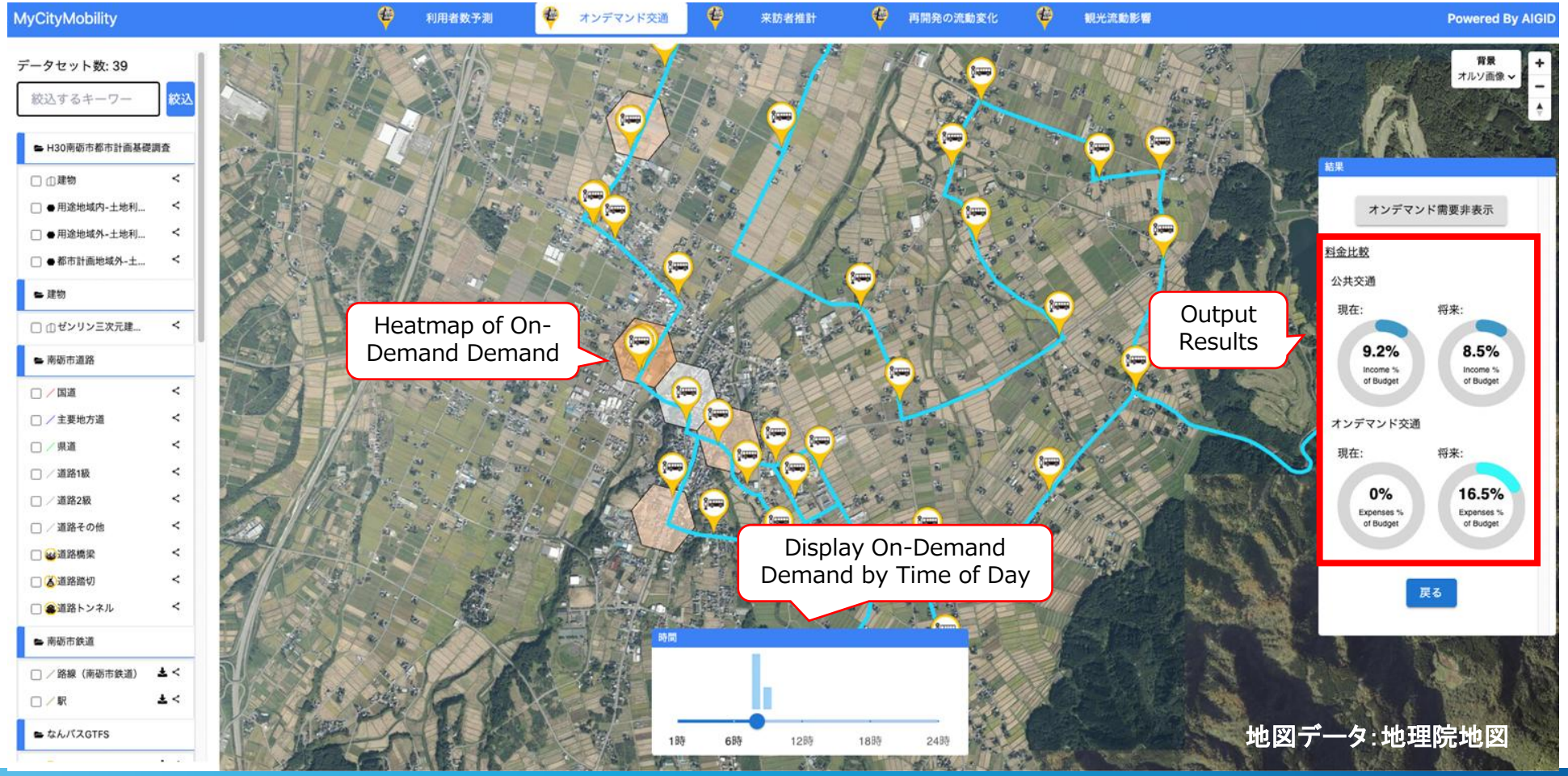


b) Implementation of On-Demand Transportation (Input)

- Users could select or upload a public bus route, decide service reductions, and customize on-demand transportation parameters (vehicle type, fleet size, fare structure, etc.).

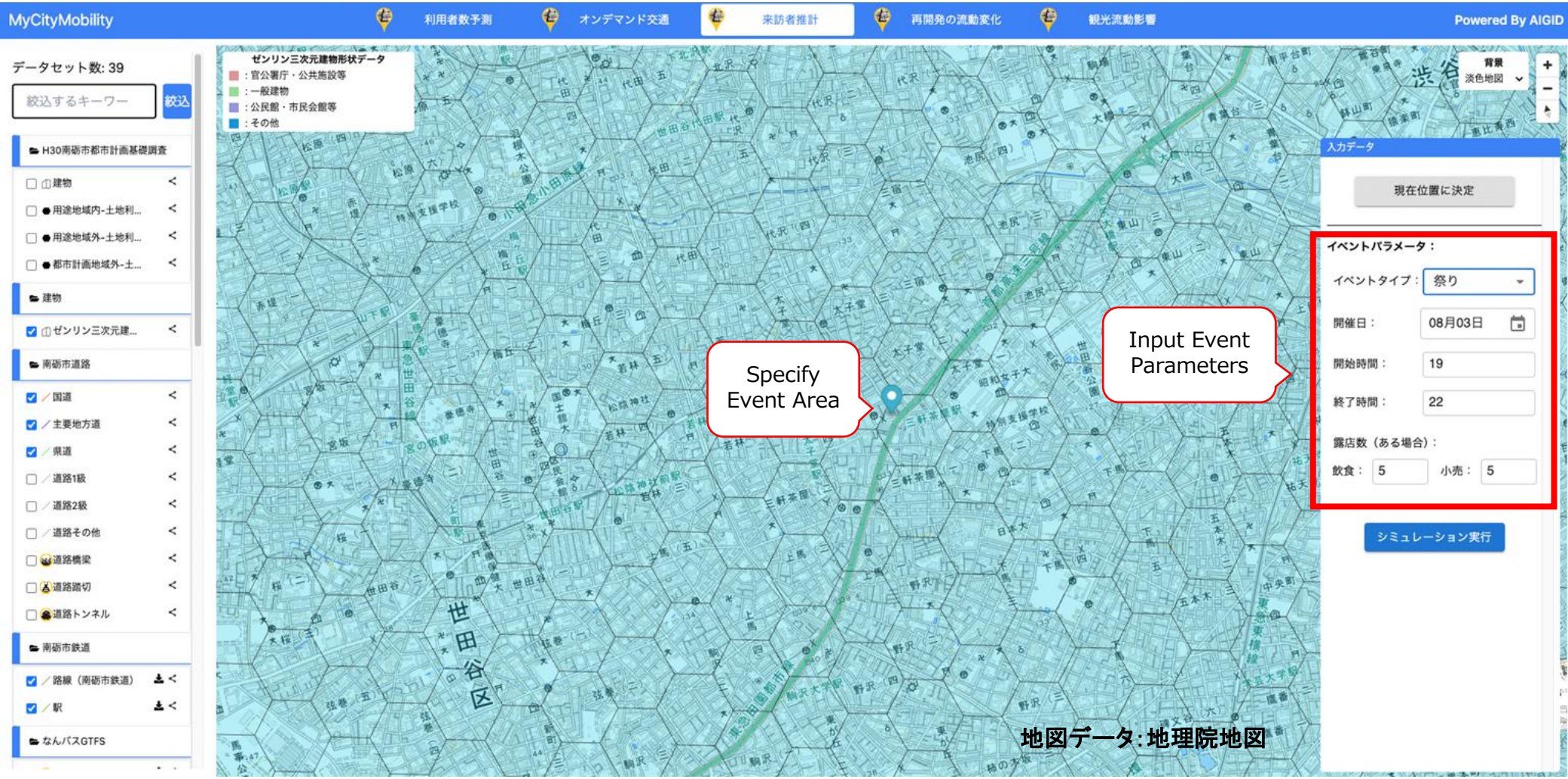
b) Implementation of On-Demand Transportation (Output)

- The system visualizes before-and-after budget comparison results for public transport versus on-demand services, as well as potential demand by time of day.
- Within this fiscal year, the fare simulation will be enhanced to support nationwide deployment across public transport routes.



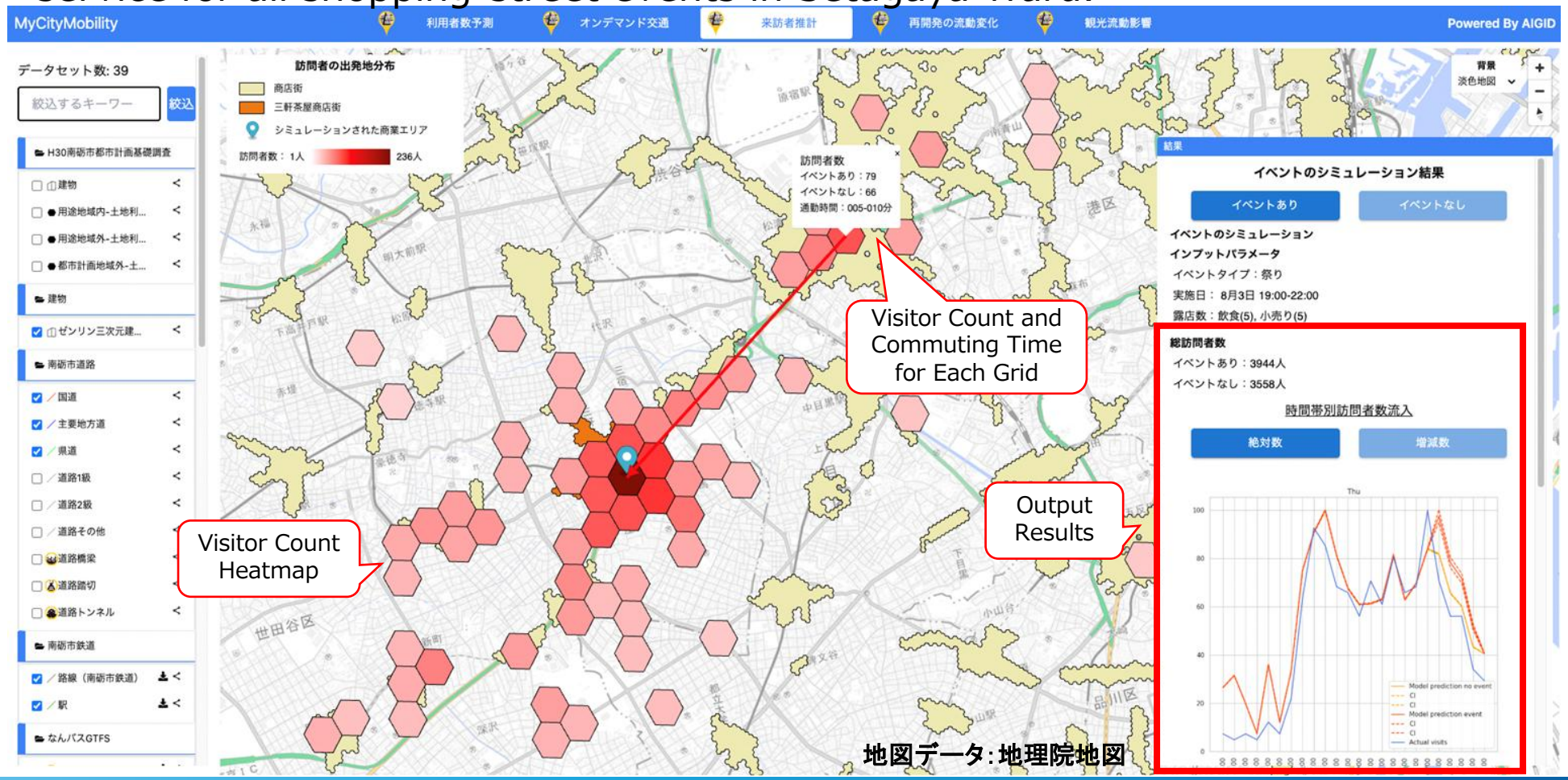
c) Estimates of visitors to specific areas (Input)

- The function to appoint the event area and input parameters related to the event (such as event type, date and time, number of booths, etc.) has been implemented.



c) Estimates of visitors to specific areas (Output)

- Visualize total visitors with and without an event for the Sangenjaya shopping district, the inflow by time of day (including commuting hours), and the distribution of visitor origin locations.
- By the end of this fiscal year, we plan to roll out an event-visitor estimation service for all shopping-street events in Setagaya Ward.



Development & Refinement of Pseudo-People-Flow Data

Enhancement of Accuracy and Quantification of Uncertainty in Pseudo-People-Flow Models through the Integration of Fragmented real Human Mobility data

Data Overview

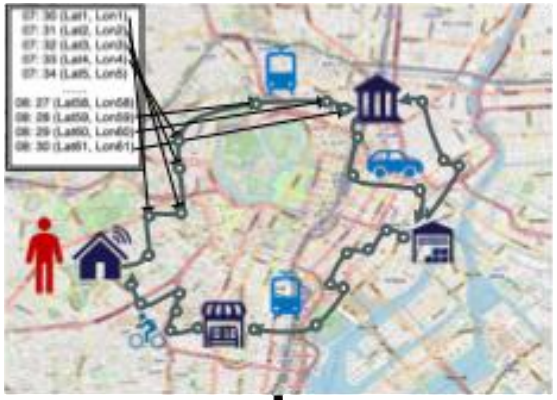
- Based on open statistical data and agent models using common learning parameters, estimate people's typical daily activities, locations, modes of transportation, and travel routes at any given moment, and create synthetic data that can represent these behaviors in a pseudo manner.

①Household Estimation model
世帯推計モデル

What to do at What time of day?

②Activity Generation model
活動生成モデル

⑤Route Choice / Spatial-temporal Interpolation
経路選択・時空間内挿入処理



Pseudo People Flow Dataset
擬似人流データセット

From Where to Where?

④Transportation Mode Choice model
交通手段選定モデル

Create Trajectory on road

By what means of transportation?

③Activity Location Selection model
活動場所選定モデル

Data Provision & Update Status

- After releasing Ver 1.0 in April 2022, Ver 1.1 and Ver 1.2 were released with bug fixes, and Ver 2.0 will be released in August 2024.

Accuracy Evaluation

	ver1.2	ver2.0	Considerations
Mesh Population	Correlation coefficient with mobile data: 0.78 at 500m resolution, 0.90 at 1000m resolution.	Improved correlation coefficient: 0.83 at 500m resolution. By introducing POI data, more rational locations were selected. 0.90 at 1000m resolution.	At the 1km resolution, there was only slight improvement in accuracy due to insufficient improvement in destination selection model.
OD Volume	Confirmed correlation of 0.78 or higher with SoftBank's motion statistics data at the municipal level.	Confirmed correlation of 0.75 or higher with motion statistics data. (Some areas had no OD volume due to insufficient POI data, but this was fixed.)	Further adjustment is needed in the behavior patterns, activities, and the frequency of incidental activities.
Cross-Sectional Traffic Volume	There were differences in correlation rates with observation points, with the overall traffic volume tending to be underestimated.	By using vehicle ownership rates by prefecture, a model replicating vehicle-centered rural areas and public transport-centered urban areas was created. Cross-sectional traffic volume decreased compared to Ver 1.2.	Quantitative evaluation of traffic volume from logistics is necessary, and the deficit in pseudo-people-flow data should be confirmed.
Trip Count	The total OD volume in motion statistics is 9,820,973. Ver 1.2 had 5,400,525 trips.	Ver 2.0 had 4,994,246 trips, an 8% decrease compared to Ver 1.2.	PT survey data suggests the number of trips per person per day has decreased from 2.8 in 2008 to 2.6 in 2018. This is believed to be the cause.
Traffic Mode Share	The model was uniform nationwide, resulting in a car-centered movement pattern where bus usage could not be reproduced.	The model was refined to more accurately replicate regional differences, especially between the three major metropolitan areas and rural areas. Bus usage was also successfully reproduced.	Compared with traffic characteristic values for cities in FY2021, there is still room to further improve the share of cars, buses, and trains.

Web API Development & Community Bus Response

- Existing major routing libraries struggled to collect community-bus route information, so their data weren't fully reflected—resulting in zero-ridership estimates in some areas.
- We rapidly developed an additional Web API, GetGTFSBusRoute, which—by simply supplying GTFS data as input—calculates bus routes and travel times without relying on those libraries.
- We're now conducting sample-based nationwide validation, and once any GTFS dataset is available and published, we plan to enable ridership estimation wherever that data exists.

		バル研 駅すぱあと	ナビタイム	ジョルダン 乗換案内	Google Map API
提供形態 (API/SDKなど)		APIとSDK両方	API	Biz Basic、API、SDK Open API	JavaScript API SDK
カバレッジ	路線バス	427社、約164,210停留所、約30,780路線	413会社	372社、25,000系統弱	情報なし
	コミュニティ	466自治社、約54,290停留所、約6,960路線	1199会社	413社、3,000系統弱 ※2019年説明資料より	情報なし
URL		https://ekispert.jp/about/spec	https://www.navitime.co.jp/serviceinfo/buscompanylist/	https://biz.jorudan.co.jp/service/biz_basic.html https://norikae.jorudan.co.jp/openapi/ https://www.mlit.go.jp/common/001289612.pdf	https://developers.google.com/maps?hl=ja
その他の情報		現在、人流WebAPIサービスは利用しています	・月間50,001アクセス以上の価格につきましては、別途のお問合せ必要 ・オプション機能があるものの、別途費用がかかる	・Open APIは路線バス非対応 ・『乗換案内Biz』の主要な機能をすべてAPIで利用可能	・日本全国における、公共交通機関に関する経路探索がNG（海外・車OK）

Comparison of Bus Coverage Among Major Route Search Service Providers

1.9. GetGTFSBusRoute

API名	GetGTFSBusRoute					
URL	https://pflow-api.csis.u-tokyo.ac.jp/webapi/GetGTFSBusRoute					
機能	任意の点座標（起点、終点）より、それら地点を結ぶ道路及び GTFS のバス経路を取得する。 バスを主とした公共交通手段を基本として経路を選択する。（バスの利用が必要条件となる）					
Content-Type	text/plain					
文字コード	Shift-JIS					
データ形式	URL エンコード					
リクエスト	POST					
引数	No	変数	項目名	型式	必須	備考
	1	UnitTypeCode	座標単位指定	Integer	○	1：度分秒 2：度
	2	StartLongitude	起点：経度	Double	○	世界測地系
	3	StartLatitude	起点：緯度	Double	○	
	4	GoalLongitude	終点：経度	Double	○	
	5	GoalLatitude	終点：緯度	Double	○	
	6	AppDate	日付	Char	○	西暦年月日 YYYYMMDD
	7	AppTime	時刻	Char	○	時分 hhmm
	8	StartGoalType	出発／到着指定	Integer	○	1：出発、 2：到着
戻り値	・正常終了時：GeoJSON 形式のテキスト、異常終了時：エラー番号 ・マッチング処理による経路とバス停情報 ・戻り値の詳細は 1.9.1. GetGTFSBusRoute 戻り値詳細参照					
解説	○引数「座標単位指定」で入力した値により、入力の経度、緯度項目の形式が異なる ・座標単位指定=1 の場合：度分秒単位 dddmmss.sss <例>139° 51′ 8.152″ → 1395108.152 ・座標単位指定=2 の場合：度単位 ddd.dddddddd <例>139.85226444 ○引数「座標単位指定」で指定した座標単位が「1：度分秒」であっても、出力の座標は度単位で出力される。 ○本 API は、路線バスの利用を前提としている。 ○戻り値の図形は経路のバス停情報であり、起点から経路に沿った順に出力される。 ○日付と時刻は、バスの経路探索を行う際の出発日時/到着日時として使用される。					

Expanded Web API Specifications

Case Study – Hama-Chidori Bus in Kobe City

- To assess the feasibility of increasing community bus services in Kobe City, Pseudo-People-Flow data was utilized to conduct demand forecasting based on real-world conditions that conventional surveys could not fully capture. This approach not only helps improve the convenience for bus users but also demonstrates new possibilities for making swift and effective short-term policy decisions.

Hama-Chidori Bus Route and Local Resident Distribution

1.Current Settings

- Operation Hours: 9:00 AM to 5:00 PM
- Frequency: One bus operating once per hour

2.Increased Service Scenario

- Add one more bus to operate every 30 minutes

3.Usage Considerations

- The most frequent usage is from Suma Station to the mountaintop
- Due to the hilly terrain, pedestrian burden is weighted: 1.2× for general users and 1.5× for elderly users

4.Regional Characteristics Considered

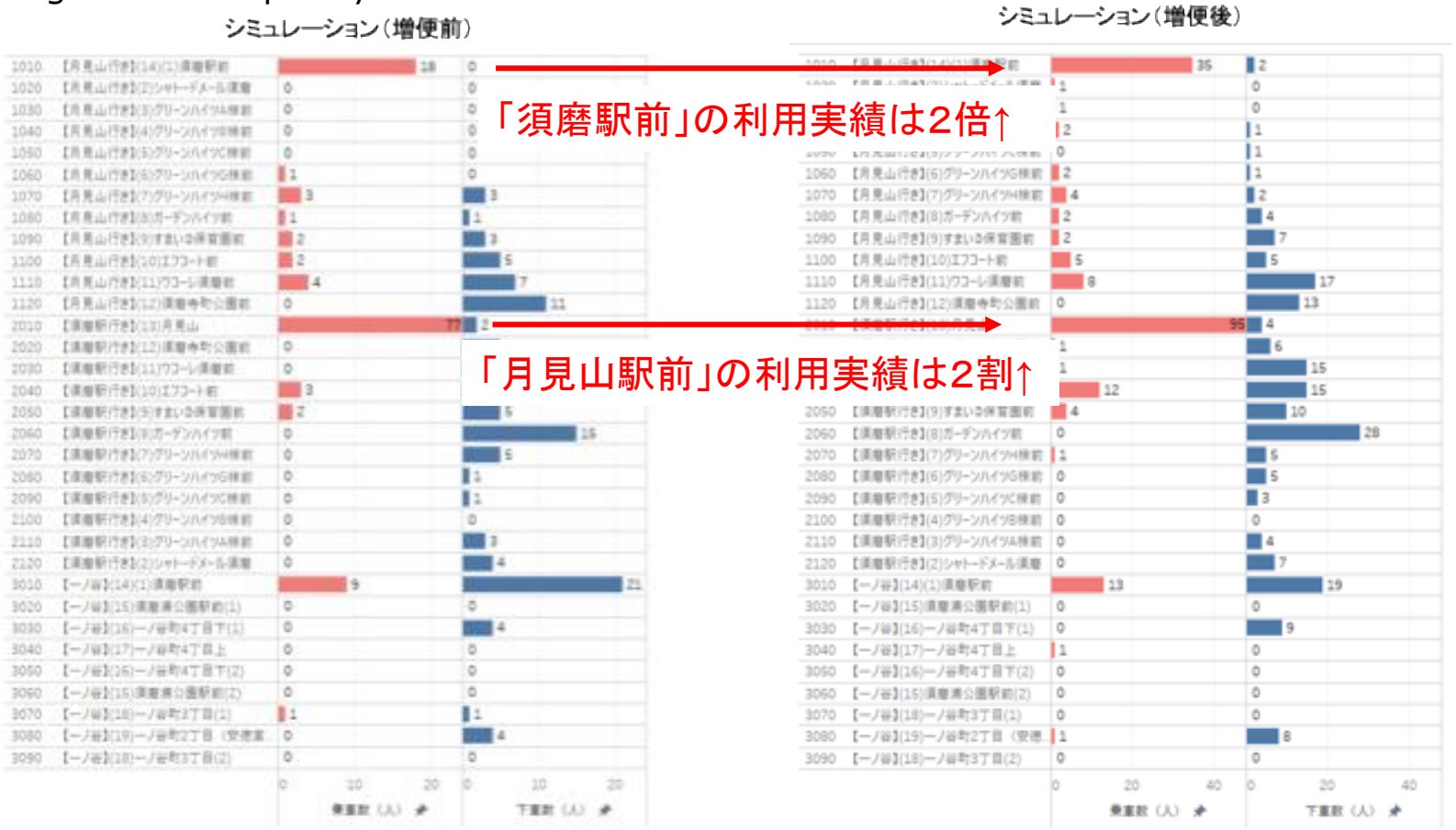
- Vehicle ownership rate in Suma Ward is set at 0.42

5.Transport Mode Selection Criteria

- The cost of each transportation mode (car, walking, bus, others) is compared, and the mode with the lowest cost is selected
- Cost is calculated as:Travel Time × Value of Time (1,000 yen/hour) + Fare + Physical Burden

Bus Usage Simulation: Comparison Before and After Service Increase

- Before the service increase, the actual average daily ridership was about 100 passengers. The simulation using Pseudo-People-Flow data estimated 123 passengers per day—slightly overestimated but closely aligned with actual boarding numbers at each stop.
- In the post-increase scenario, the average waiting time was reduced from 60 minutes to 30 minutes, and the final bus was extended to 6:00 PM. As a result, ridership increased by approximately 1.5 times. This demonstrated a sustainable balance between revenue and operating costs, highlighting the necessity of increasing service frequency.



Community Building Through Hands-On Workshops and Challenges

- At the 33rd GIS Conference, a workshop (hands-on + discussion) was held, where methods for utilizing the data and the code for generating it were openly shared. Over 30 participants (both in-person and online) deepened their understanding through live demonstrations and coding exercises, and shared feedback.
- However, a challenge emerged: knowledge sharing among researchers has not progressed sufficiently, and communication has largely been one-way from the administrative office. To address this, efforts are underway to establish an active online community via Slack, aiming to create a vibrant space for discussion and information exchange by the end of the fiscal year.

	イベント・企画		支援サービス	
新規利用者増加	データ利活用チャレンジ主催	課題間コラボ及び分野融合	JoRAS mdx GakuNin RDM JoRASやGakuNin RDMサービスとの連携	
既存利用者	ハンズオン・パネル討論等の企画	学会・シンポジウム等との連携	WebAPIサービスよりデータ提供・処理	SlackWorkspaceで交流の場を作る

Community-Building Framework

Hands-On Workshop

Organizing Study Groups for Social Implementation

Organizing Study Groups for Social Implementation

- Starting in FY2024, a research workshop composed of experts from industry, government, and academia has been established. It is held quarterly to discuss the validity of the research and development as well as its social implementation.

Past Research Workshops:
- 1st Session: June 21, 2024
- 2nd Session: September 20, 2024
- 3rd Session: December 20, 2024
- 4th Session (Planned): March 17, 2025

【委員構成】

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Coordination with Participating Municipalities and Implementation Use Cases

- Several municipalities were selected from the 257 social experiment sites surveyed in the previous fiscal year.

【Key Initiatives of Participating Municipalities in the Research Workshops】

参加自治体	特徴・当該研究と関連するユースケース
静岡県裾野市	東大DSSと包括協定、ユースケースa,d
富山県南砺市	東大DSSとデジタル化に関する包括協定、田中市長が自治体ライドシェア会長
静岡県小山町	予約・乗車システムを活用したデマンドバスによる地域生活圏のモビリティの充実（Digi田甲子園 2022夏）（ユースケースb）
東京都世田谷区	東大関本研、三軒茶屋商店街連合会と連携して商店街デジタルツインプロジェクト実施中（ユースケースc）
愛媛県伊予市	R4年度内閣府社会実験優良事例（中山間地域における自動運転バスを活用した健康MaaSの実現：ユースケースa）
愛知県岡崎市	R4年度内閣府社会実験優良事例（広域アプリ連携で拠点施設からまちなかへの人流波及事業：ユースケースc）
兵庫県神戸市	市内コミュニティバス「はまちどり」の増便予測において、擬似人流データを活用した研究を実施（ユースケースa）

【ユースケースの分類】
a) 公共交通の新規建設あるいは増便等による利用者数の増分の推定
b) 公共交通減便によるオンデマンド交通の導入
c) 特定エリアでのイベント実施・歩行者天国化等による来訪者推計
d) 道の駅や大型ショッピングセンター建設、駅前再開発等による周辺の流動変化
e) イベント情報の発信強化による観光流動等の変化
f) その他

Identification of Additional Requirements for the Prototype

- We conducted individual consultations with the three municipalities participating in the research workshops to identify additional prototype requirements and discuss the future outlook for the Mobility Digital Twin.

【Summary of the Discussions】

対象自治体	意見（抜粋）	利用シーンでの今後の展望
静岡県小山町	・デマンドバス事業を実施し、ライドシェアも検討中。費用が懸念となり気軽に新たなモビリティを導入できないため、モビリティデジタルツインで事前にシミュレーションできると良い。	・ライドシェアとデマンドバスを考慮した、適切な運行台数の検討 ・人口データなどを用い、稼働するエリアや必要台数、運行時間のシミュレーション
愛知県岡崎市	・街中に人を呼び戻す取り組みを進めている。事業実施後、効果検証の際にモビリティデジタルツインを活用できると良い。 ・桜祭りを実施しているがどれほどの集客効果があるのか、把握したい。	・イベントエリアでの出店者誘導のテストマーケティング ・季節イベント実施時の周辺商店街への波及効果検証 ・季節イベント実施時の周辺道路への渋滞の影響や渋滞回避の案内、P＆Rの効果検証
兵庫県神戸市	・はまちどりバスの事例では、疑似人流データを活用して実態に基づく需要予測を実施したことで、増便に繋がった。 ・自治体職員でも活用できるようなUIの開発（データの入力と出力）や、shpデータ以外にもバス停や路線に着目した簡易的な表示、季節変動の影響を考慮した利用者数の係数補正ができると良い。	・バス路線延伸時における、疑似人流を活用した、利用者数の変動や収支率のシミュレーション ・既存収集データを活用した、実証運行の短期化

Activity Plan and Outlook for the Next Fiscal Year

Prototype Improvement

Additional requirements obtained from consultations with participating municipalities will be incorporated into the prototype during the first half of the fiscal year.

High-Resolution Analysis

During the discussions, there was a demand for micro-level analysis of routes, sections, and full-road facilities. As a result, the spatial resolution of Pseudo-People-Flow data will be improved to not only use meshes but also traffic volume data by time of day. This will enable the use of Digital Twin technology in micro-level areas.

Expansion of Stakeholders

Currently, the research workshops involve municipalities, experts, and SIP stakeholders. To facilitate the horizontal expansion of municipalities, the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) and its transportation-related departments will be invited to join as committee members.