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

2024.03

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

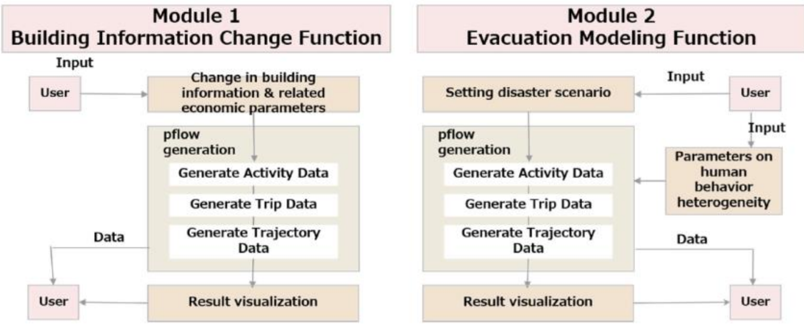
Overview

Background & Purpose

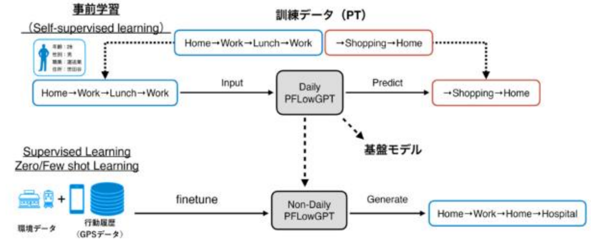
- There are many social experiments in Japan related to Smart City and MaaS, but many of them are left unfinished. Also, there is no evaluation platform to assess hypotheses for behavior modification, alternative approaches, or scalability.
- In particular, the operating body of social experiments are already busy with project implementation and are reluctant to engage in additional tasks due to the time, cost, and other factors involved in data acquisition and analysis.
- It would be beneficial to have a framework that allows for effective use by evaluators or enables the operating body to conduct objective evaluations themselves.
- While digital infrastructure is gradually being developed, there is currently no "digital twin platform" that can be used by practitioners.
- This has the potential to evolve into a tool for explaining to local residents as well.

Research and development overview

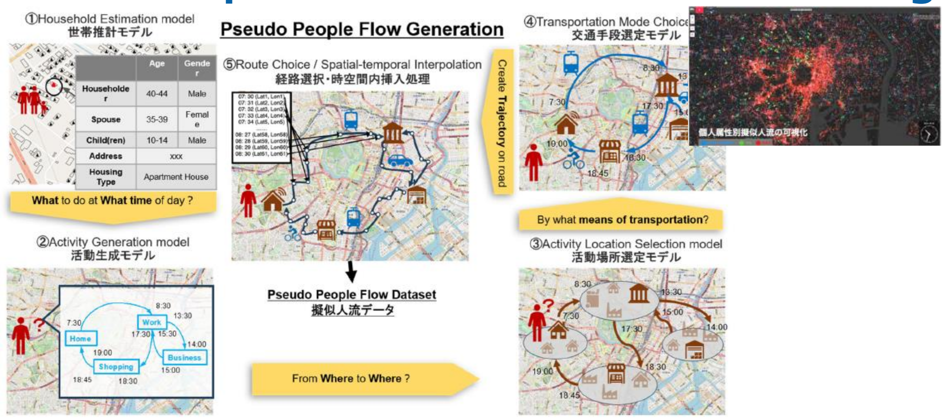
（1） Categorization of Mobility Simulations and Design of Digital Sandbox Platform



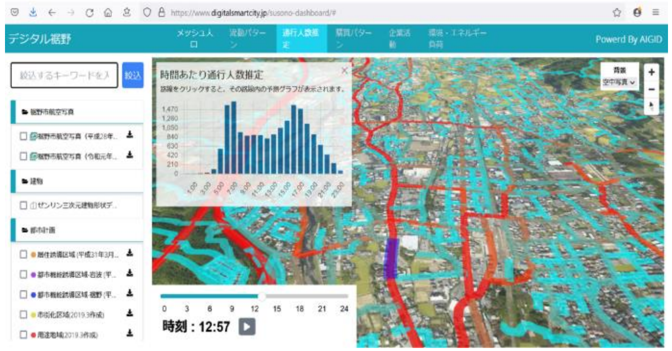
（3） Enhancement of Accuracy and Quantification of Uncertainty in Pseudo-People-Flow Models through the Integration of Fragmented real Human Mobility data



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



（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	

The goal of the research and development

- Final Goal
  - ✓ By the end of 2025, the goal is to implement and evaluate 3-5 existing or past social experiments on a Digital Sandbox platform. Additionally, collaboration with SIP Smart Mobility and other related themes will be encouraged to increase usage opportunities.
  - ✓ Initially, simulation services will be developed to calculate the impacts and effects (number of visitors, sales, congestion, accidents, etc.) on the web, considering scenarios such as..
    a) Estimation of the increase in the number of users due to the new construction or increased frequency of public transportation.
    b) Implementation of on-demand transportation due to reduced frequency of public transportation.
    c) Estimation of visitors due to events or pedestrianization in specific areas.
    d) Analysis of flow changes in the surrounding areas due to the construction of rest stops, large shopping centers, or station redevelopment.
    e) Analysis of changes in tourist flows due to enhanced dissemination of event information.
  - ✓ By the end of fiscal year 2027, the final goal is to have a visible business model and establish a consortium, including user municipalities and private companies, to create a user community and aim to use the platform within that community. Additionally, approximately 10-15 typified cases, covering a wide range of scenarios, will be constructed.

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

Categorization and organization of past social experiments and their application potential of Digital Twin

Categorization and organization of past social experiments

- A survey was conducted on 257 cases of social experiments conducted by the Cabinet Office, MLIT (Road Bureau, City Bureau) and other entities. The results showed that 53% of the cases fit into categories a) to e).

Subject

Road Bureau (H25～R4)	Cabinet Office (R3～R4)	City Bureau	Total
103	113	41	257

①Grouping The cases were classified into categories a) to e) and f) others

Group	Number Applicable	Road Bureau	Cabinet Office	City Bureau
a) Estimation of the increase in the number of users due to the new construction or increased frequency of public transportation	55 (21%)	14	38	3
b) Implementation of on-demand transportation due to reduced frequency of public transportation	24 (9%)	1	22	1
c) Estimation of visitors due to events or pedestrianization in specific areas	23 (9%)	14	7	2
d) Analysis of flow changes in the surrounding areas due to the construction of rest stops, large shopping centers, or station redevelopment.	17 (7%)	9	2	6
e) Analysis of changes in tourist flows due to enhanced dissemination of event information	54 (21%)	11	39	4
f) Others	121 (47%)	64	31	26

a)～e) : **136 cases are applicable (53% of the target cases)**

※ There are cases that fall into multiple categories

Reproducibility in Mobility Digital Twin

- It is especially important to be able to retrieve the various conditions and results of the social experiment.
- At the preliminary level, it appears that reproducible experiments using Mobility Digital Twins can be conducted based on publicly available reports for approximately 7.7% of the total cases

②Case Selection

Cases that meet the following conditions were selected from categories a) to e):

- Each case is consistent with the classification theme
- Input information can be configured
- There is a high potential for prediction using foot traffic data

36 cases are applicable (14% of the target cases)

③Grouping of numerical information

Cases that meet the conditions of category ② were further classified based on the availability of numerical information for input and output data

Numerical information for input and output data	Number Applicable
Yes	**20**
No	16

From the **20 cases** with numerical information available (7.7% of the target cases), **3 cases** were selected that are considered to have a high potential for simulation using people flow data

Organizing the cases of social experiments

Group	a) Estimation of the increase in the number of users due to the new construction or increased frequency of public transportation	b) Implementation of on-demand transportation due to reduced frequency of public transportation	c) Estimation of visitors due to events or pedestrianization in specific areas
Experiment/ Business Name	Realization of Health MaaS utilizing Autonomous Bus in Mountainous Regions Regions	Compact Smart City Park Data Dashboard	Flow of Pedestrian Traffic from Base Facilities to Downtown through Wide-Area App Collaboration
Overview	We will consider the collaboration between local businesses and provide multiple services such as health consultation services within autonomous vehicles, in order to explore cross-industry collaboration rooted in the community.	We will implement a multi-mobility, multi-service business that utilizes AI for on-demand transportation and optimizes transportation methods through the analysis of pedestrian and traffic data. We will also strive to achieve seamless reservation services in collaboration with events and other initiatives. Additionally, we will carry out initiatives to promote behavioral changes in residents by utilizing local currency points and other means..	We will focus on utilizing an app to promote and showcase the attractive content and information about local businesses, in order to attract foot traffic to the downtown shopping district. Additionally, we will work on improving the management of the local shopping district through data utilization, using information such as people flow routes from the app, headcount data from existing pedestrian cameras, and inferred demographic information.
Inputs (Changes)	・Verification operation of autonomous buses ・Digital health management services ・Development of various additional services utilizing autonomous driving	・Utilization of on-demand transportation with AI ・Organizing seminars and events ・Distribution of boarding points etc.	・Integration with external apps on a wide scale ・Conducting in-app events (strategies to promote repeat visits)
Outputs	・Number of users of autonomous driving mobility services ・Number of registered users for digital health management services	・Number of passengers, number of rides ・Ridership rate etc.	・Number of participants in events in the app ・Number of check-ins by spot by day etc..
Target area	Iyo City, Ehime Prefecture (Futami area)	Toyono-cho, Osaka (West District)	Okazaki City, Aichi Prefecture(Otogawa Riverfront QURUWA Area)

・令和4年度のスマートシティ関連事業の選定結果(内閣府)
・令和4年度地域新MaaS創出推進事業地域報告書(経済産業省)
・豊能町AIオンデマンド交通の実証実験＜結果速報＞(豊能町)
・スマートシティ実装化支援事業 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報告書（令和4年度岡崎スマートコミュニティ推進協議会）

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

System Design of Mobility Digital Twin (5 typical patterns)

Demonstration scenarios and target areas

Group	Simulation	Components	Input data	Output data	Target area
a	Estimation of the increase in the number of users due to the new construction or increased frequency of public transportation	* Extracting transportation mode selection probabilities by area type and public transportation type from foot traffic data * Building an estimation model for changes in the number of users by area type and public transportation type	* Traffic links * Withdrawal and new installation of traffic links * Traffic mode selection parameters	Number of users per point (e.g., station)	Nanto；Susono
b	Implementation of on-demand transportation due to reduced frequency of public transportation			Calculate the demand for on-demand buses (location and the price you have been paying) caused by the reduced service	Nanto；Susono
c	Estimation of visitors due to events or pedestrianization in specific areas	* Extracting changes in the value of the probability of the number of visitors for each event type from human flow data * Develop a model for predicting the rate of change in the number of visitors for each event type	* Destination selected parameter * Event parameter	Number of visitors per area/point	Sangenjaya Shopping Street
d	Analysis of flow changes in the surrounding areas due to the construction of rest stops, large shopping centers, or station redevelopment	* Extraction of visitor parameters by building and area type * Building a model to predict the number of visitors per building/area type	* Building withdrawal and exit information	Number of visitors per link	Susono
e	Analysis of changes in tourist flows due to enhanced dissemination of event information	* Parameter extraction of changes in number of visitors by number of event publicity reach * Develop a model for predicting the number of visitors based on event publicity (number of reach, target audience, target area)	* Event size and location parameters * Public relations reach parameters	Number of visitors per point/area	Susono；Toki-no-sumika

Screen and process flow of each function

① Scenario Selection

Simulation scenario selection

②-a. Forecast number of public transportation users

Estimation of the increase in the number of users due to the new construction or increased frequency of public transportation

③-a. Parameter setting

User sets up a new station and enters traffic mode selection parameters into the system

②-b. Implementation of on-demand transportation

Implementation of on-demand transportation due to reduced frequency of public transportation

③-b. Parameter setting

User enters public transportation GTFS data and specifies target for reduction

②-c. Estimates of visitors to specific areas

Estimation of visitors due to events or pedestrianization in specific areas

③-c. Parameter setting

User specifies event area and enters event parameters

②-d. Flow changes due to redevelopment

Analysis of flow changes in the surrounding areas due to the construction of rest stops, large shopping centers, or station redevelopment

③-d. Parameter setting

User specifies redevelopment area and enters development parameters

②-e. Flow impact of tourism promotion

Analysis of changes in tourist flows due to enhanced dissemination of event information

③-e. Parameter setting

User specifies event and PR area and enters event and PR reach parameters

④ formation process

Common

Estimated generation time is visible on the user side

⑤Data output and visualization

Mobility change results are output and visualized on a background map on the tool

a) Forecast number of public transportation users (Input Configuration)

- The system will be used for changes when new public transportation systems are constructed or when additional services are added.
- The design shall also allow editing of station order, times, fares, and service increases from the timetable.

国土地理院撮影の空中写真を加工して作成

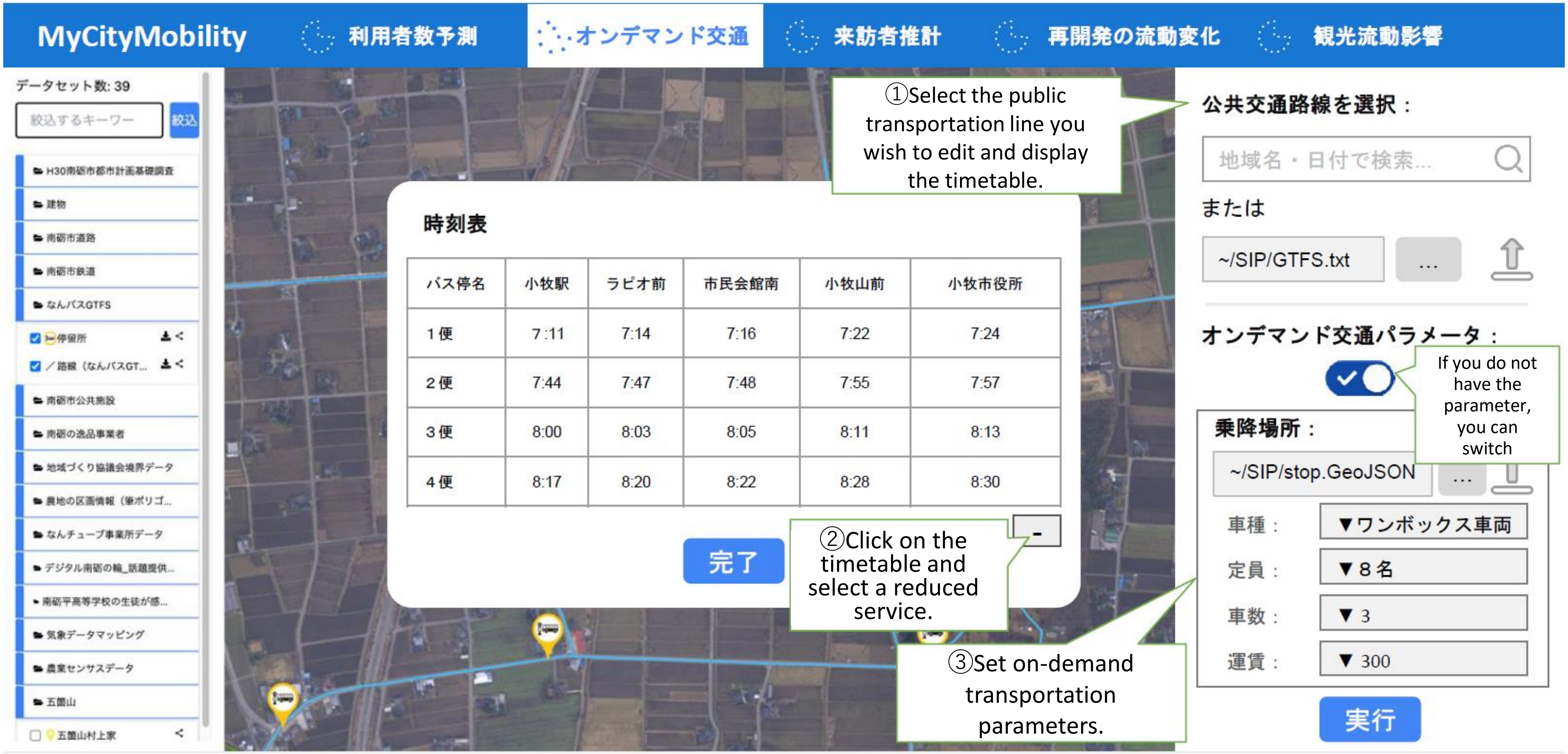
a) Forecast of public transportation users (Output)

- The total number of passengers and the estimated number of passengers per hour at each station are displayed.

国土地理院撮影の空中写真を加工して作成

b) Implementation of On-Demand Transportation (Input Configuration)

- Two patterns are prepared: (1) to look at the potential of transportation demand due to reduction/elimination of public transportation without including parameters for on-demand transportation, and (2) to include parameters such as vehicle types, fare levels, etc.

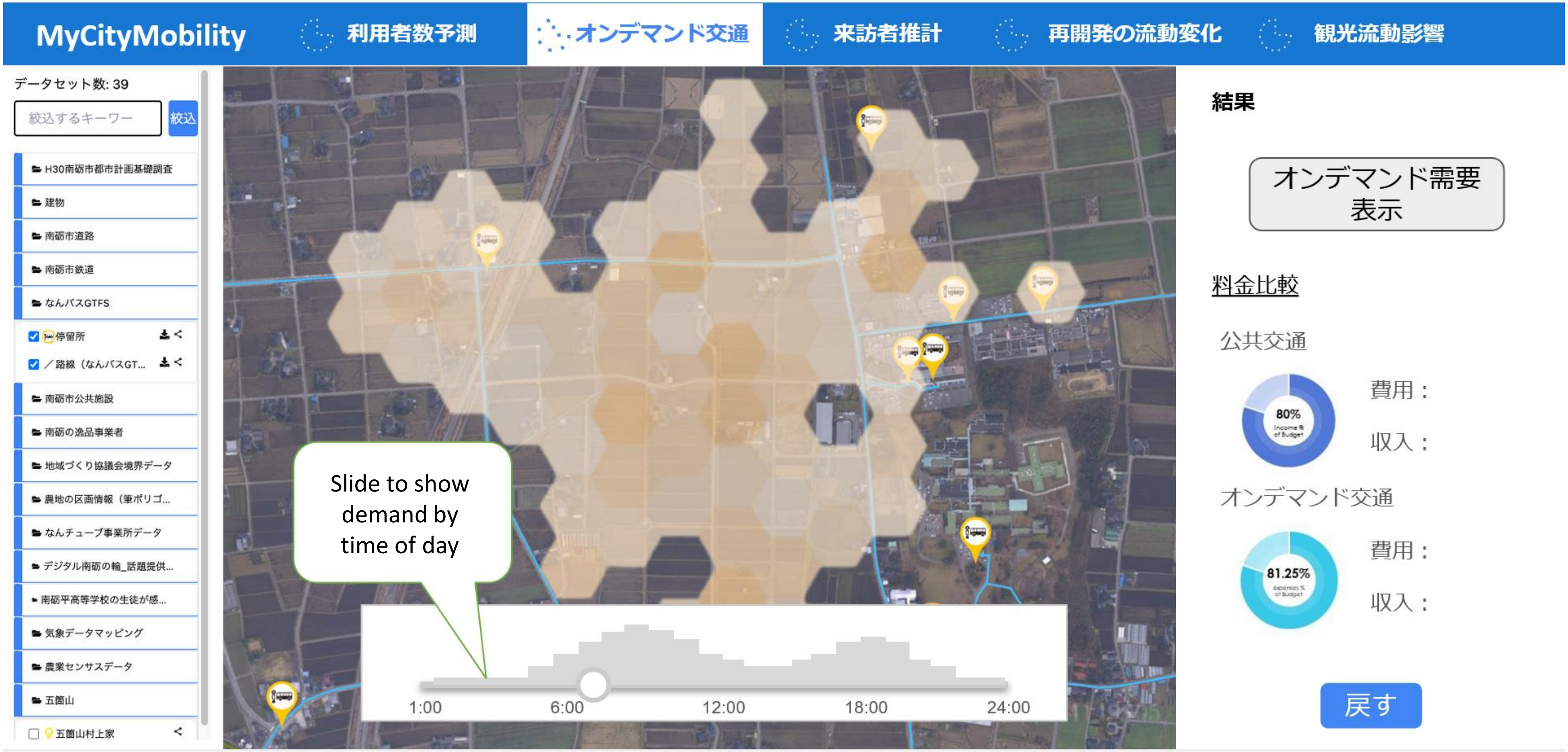


バス停名	小牧駅	ラピオ前	市民会館南	小牧山前	小牧市役所
1便	7:11	7:14	7:16	7:22	7:24
2便	7:44	7:47	7:48	7:55	7:57
3便	8:00	8:03	8:05	8:11	8:13
4便	8:17	8:20	8:22	8:28	8:30

国土地理院撮影の空中写真を加工して作成

b) Implementation of on-demand transportation (Output without parameters)

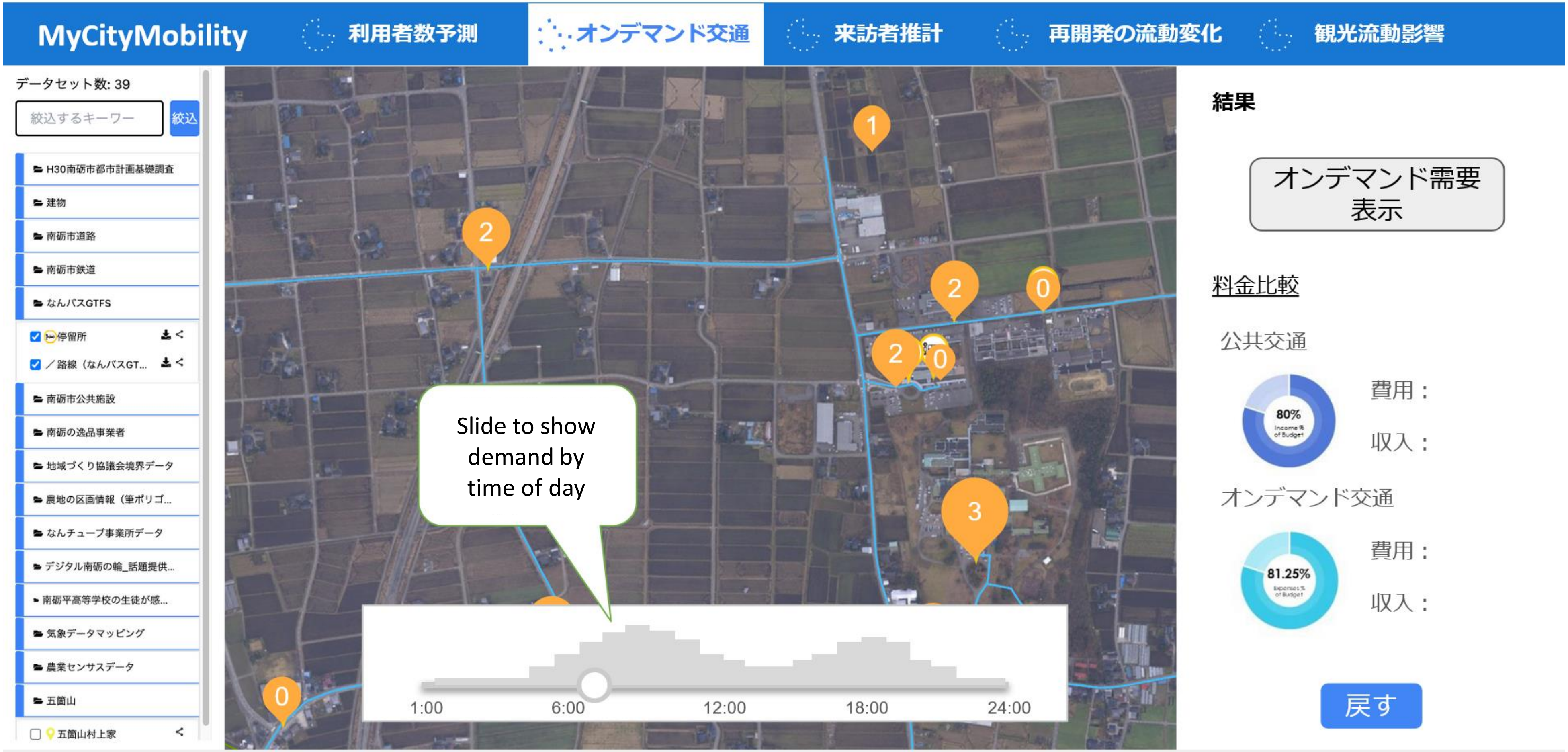
- It is expressed as a potential mapping as some aggregate value.



国土地理院撮影の空中写真を加工して作成

b) Implementation of on-demand transportation (Output with parameters)

- Comparison of rates, etc., will also be calculated.



国土地理院撮影の空中写真を加工して作成

c) Estimates of visitors to specific areas (Input Configuration)

- It will be used for pedestrian malls, changes when specific events are conducted, etc., but the design of how detailed the event parameter settings should be needs to be determined.

Google Mapを加工して作成

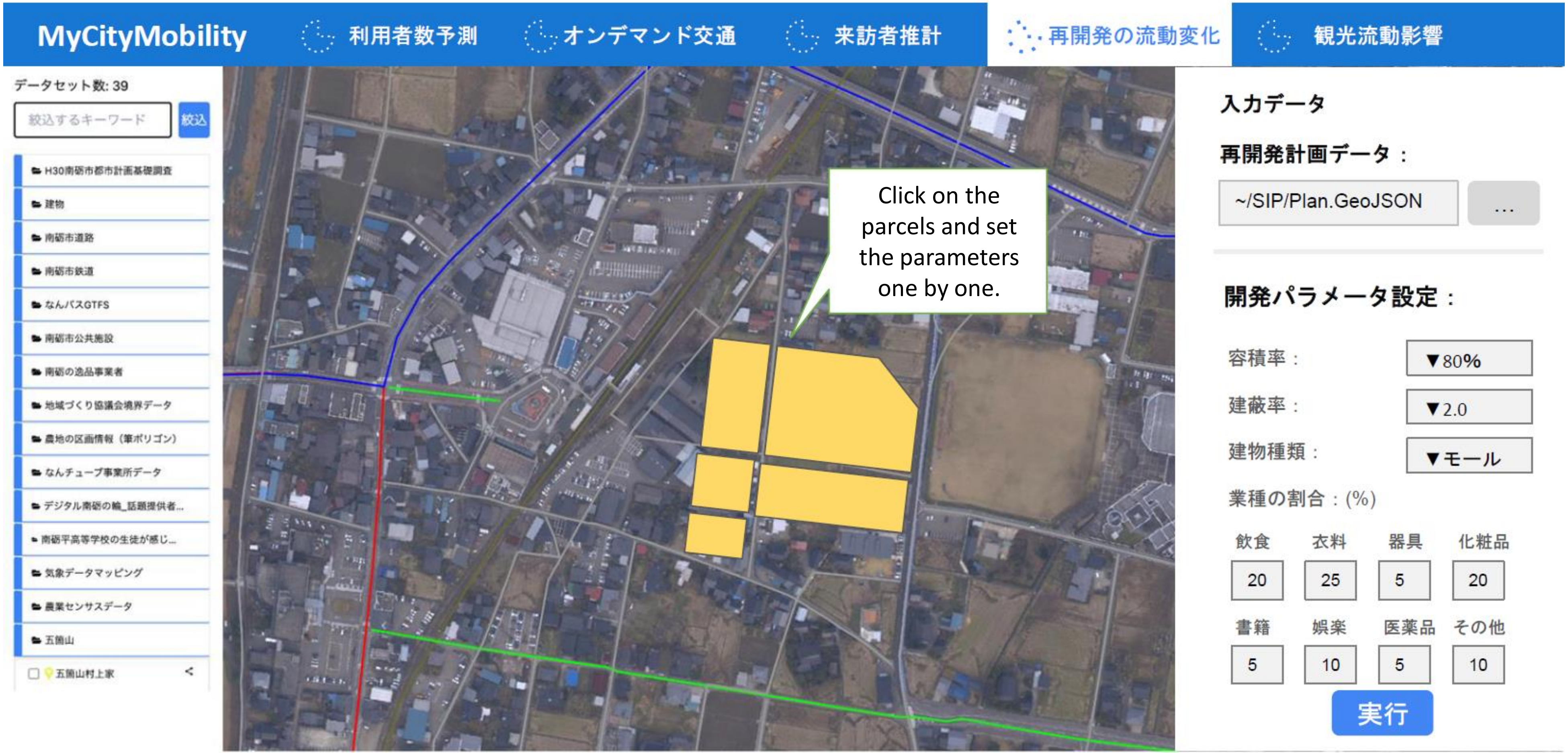
c) Estimates of visitors to specific areas (Output)

- It would be nice to include not only overall trends and maps, but also economic effects.

Google Mapを加工して作成

d) Flow changes due to redevelopment (Input Configuration)

- Used for changes during construction of rest stops/large shopping malls and redevelopment of station fronts, etc., but design is needed to determine how detailed the development parameters should be set.



国土地理院撮影の空中写真を加工して作成

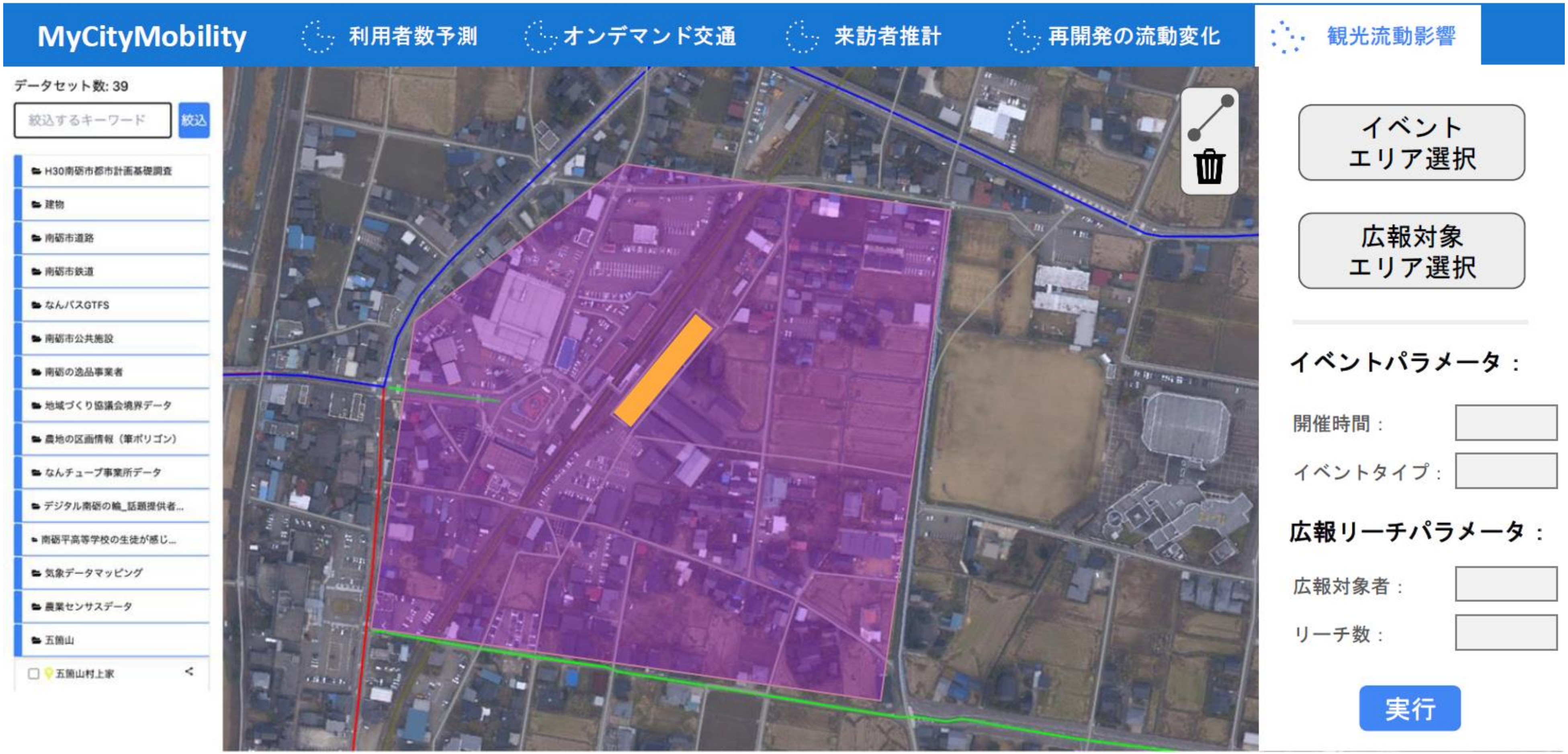
d) Flow changes due to redevelopment (Output)

- Displays the estimated number of passengers per hour on each roadway segment, etc.

国土地理院撮影の空中写真を加工して作成

e) Flow impact of tourism promotion (Input Configuration)

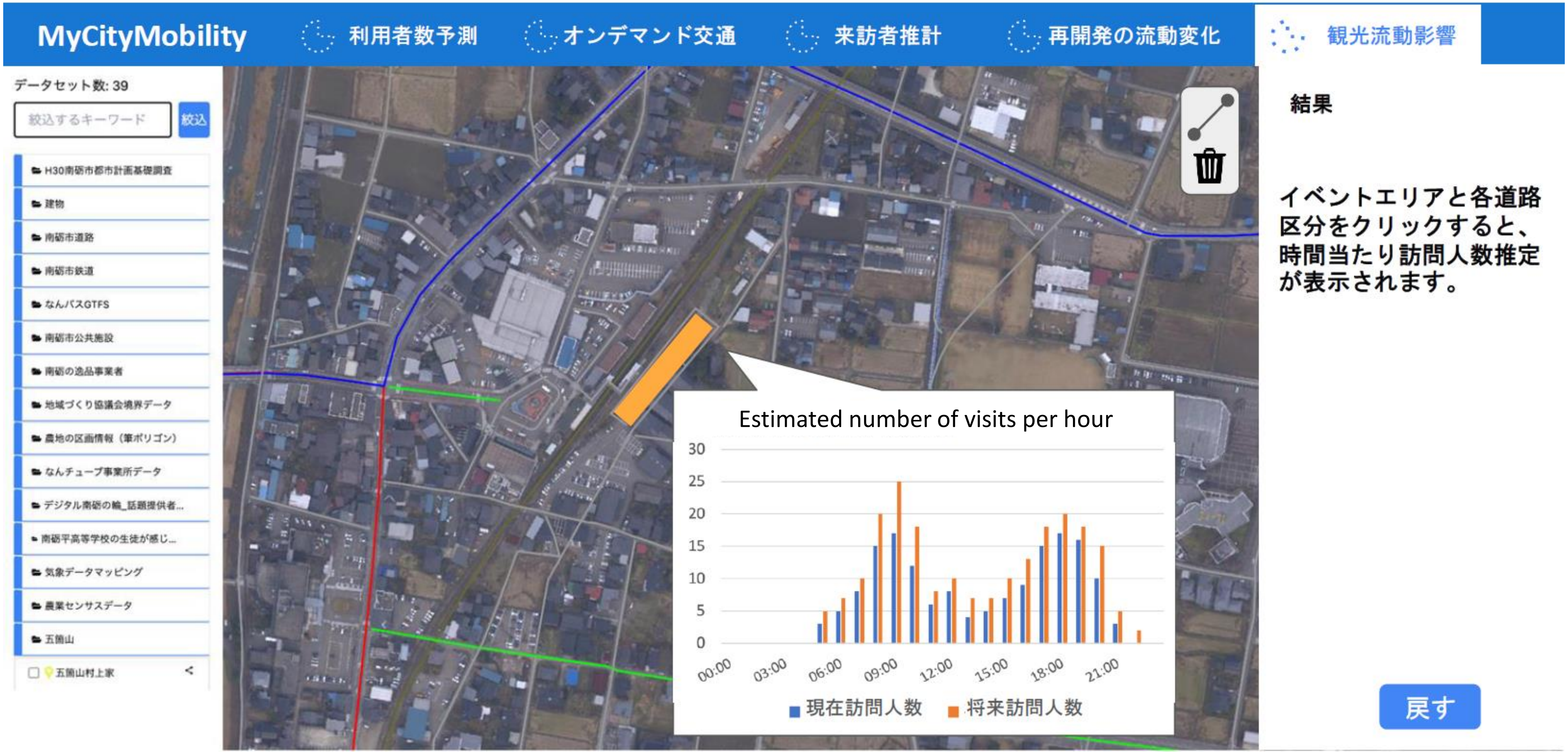
- The event parameters and PR reach parameters need to be designed in terms of how detailed they should be, although they will be used for changes when event information dissemination is strengthened, etc.



国土地理院撮影の空中写真を加工して作成

e) Flow impact of tourism promotion (Output)

- Display the estimated number of visitors per hour in the area and each road segment.



国土地理院撮影の空中写真を加工して作成

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

Improvement of accuracy in generating Pseudo-People-Flow and Application of LLM

Creating Ver.2 of Nationwide Pseudo-People-Flow

- Currently working on creating Ver2.0 for release in May.
- Web API in the first half of the year for integration into next year's Mobility Digital Twin prototype.

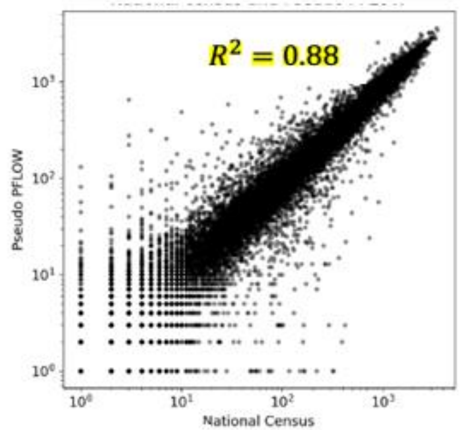
①Household Data 世帯人口データ	→		世帯分布情報更新
②Activity Data 活動データ		活動場所選定 モデル更新	POI(全国1279万か所)を 場所選択に導入
③Trip Data トリップデータ		トリップの起終点 更新	活動開始時間分布を 都市ごとに精緻化
④Trajectory Data 軌跡データ	滞在者欠損 エラーの修正	徒歩と自転車の 移動軌跡の遠回 りバグの修正	交通手段の選択を 都市ごとに精緻化
⑤Aggregated Data 人口分布 リンク交通量	滞在人口の欠 損を補正	→	結果の更新

Ver. 1.0	Ver. 1.1	Ver. 1.2	Ver. 2.0	WebAPI提供開始
2022.04.28	2022.10.08	2023.01.28	2024.03（予定）	2024.10（予定）

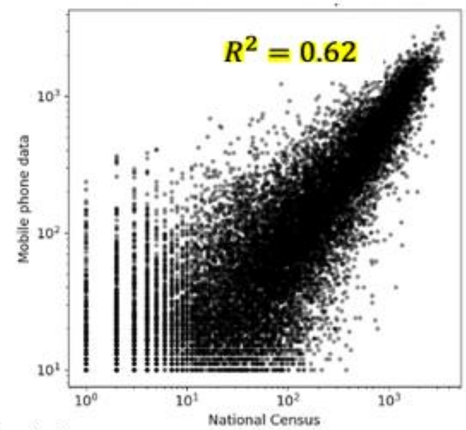
Accuracy Evaluation of Nationwide Pseudo-People-Flow

- Upon comparing the accuracy of nationwide Pseudo-People-Flow data with national census and mobile phone data, it has been determined that there is a certain level of accuracy in terms of population distribution by time period.
- However, there are areas where the volume of business trips and overall trip data is insufficient. Therefore, we will address this by incorporating improvements in future versions.

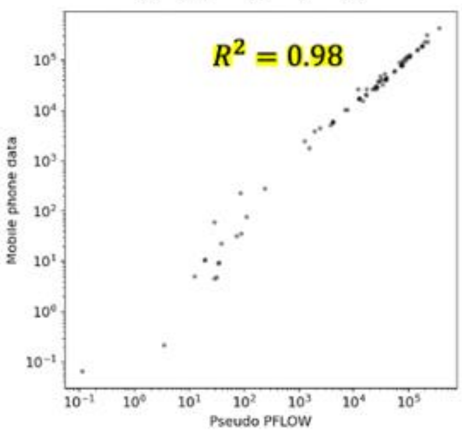
擬似人流v.s.国勢調査



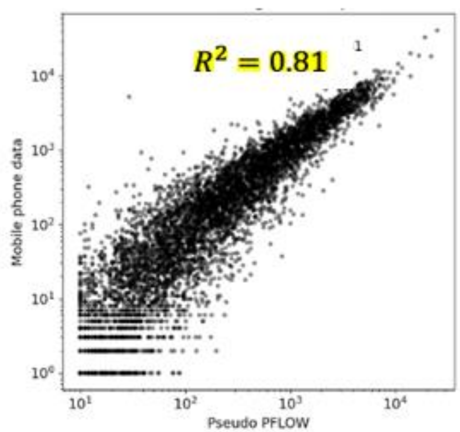
擬似人流 v.s. 携帯電話データ



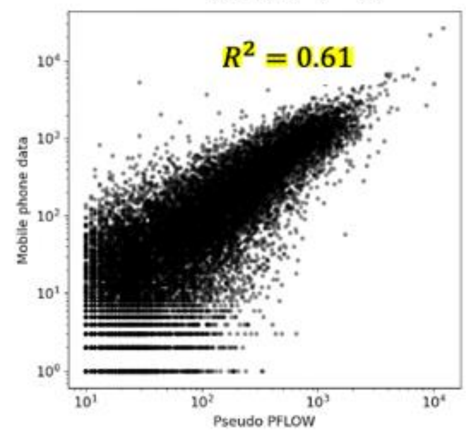
行政レベル（正午）



1km解像度（正午）

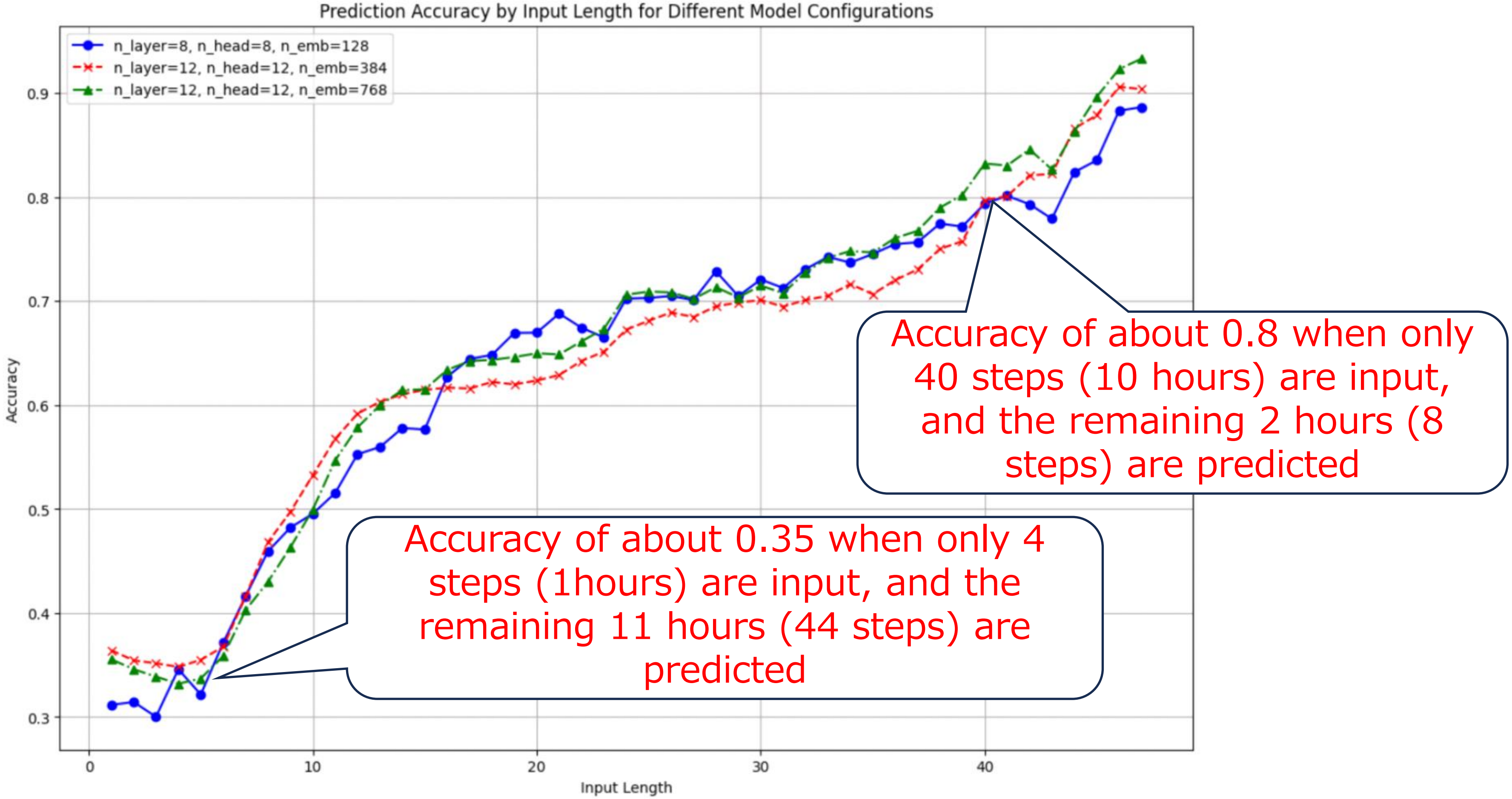


500m解像度（正午）

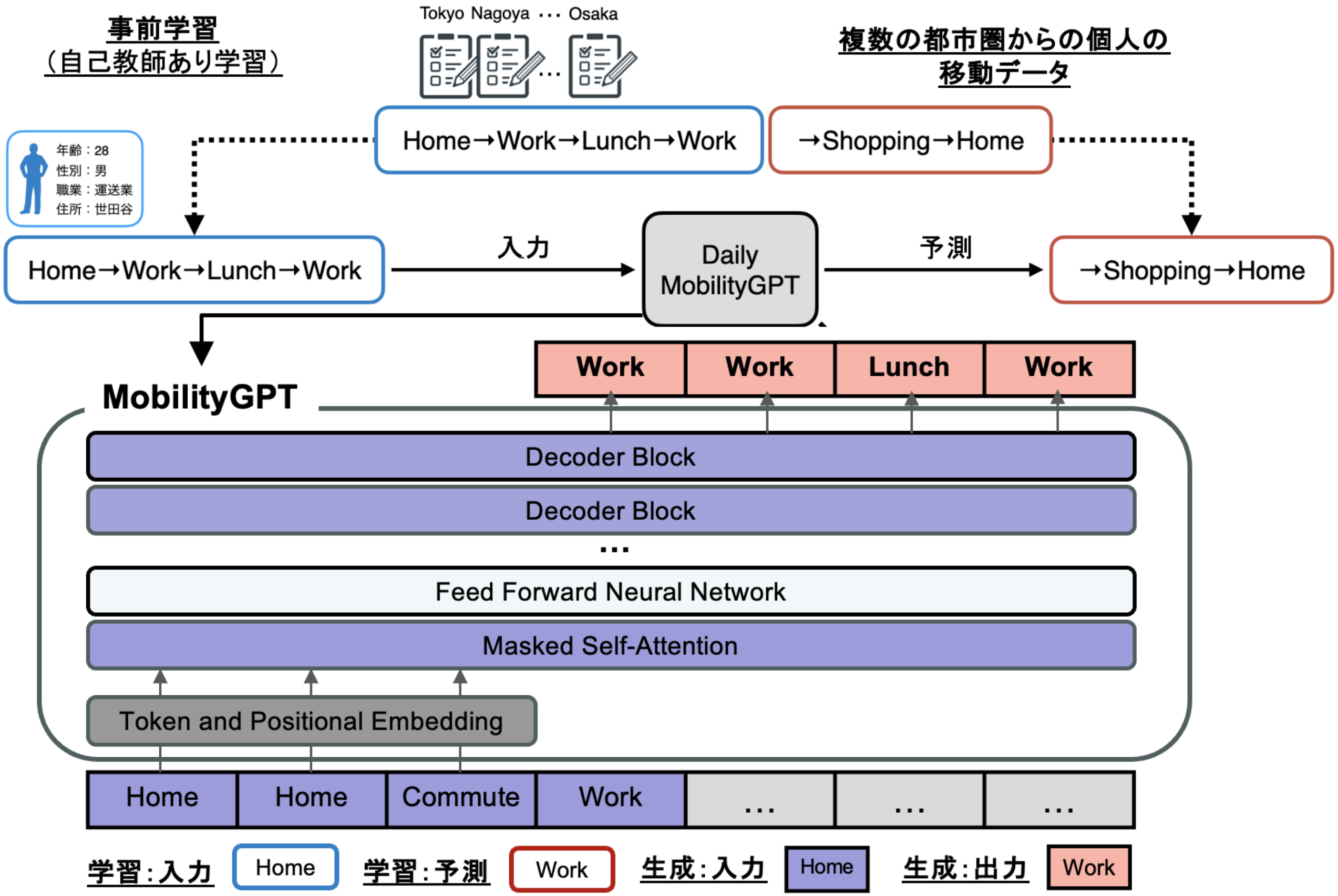


The application of LLM to Pseudo-People-Flow

- We trained and evaluated GPT2 using trip chain data (approximately 461,000 trips) from nationwide person trip surveys conducted across various regions in Japan, specifically focusing on the time period from 6:00 to 18:00 (48 time steps)
- In this case, the Pseudo-People-Flow data does not include individual attributes, and it will be used to improve the accuracy of the model.



The application of LLM to Pseudo-People-Flow, incorporating the utilization of individual attributes



コード	活動
1	男性
2	女性
3	農林漁業従事者
4	採鉱・採石従事者
5	技能・生産工程従事者
6	販売従事者
7	サービス業従事者
8	運送・通信従事者
9	保安職従事者
10	事務的職業従事者
11	技術的・専門的従事者
12	管理的職業従事者
13	その他職業
14	生徒（中学生以下）
15	学生（高校生以上）
16	主婦・主夫
17	無職

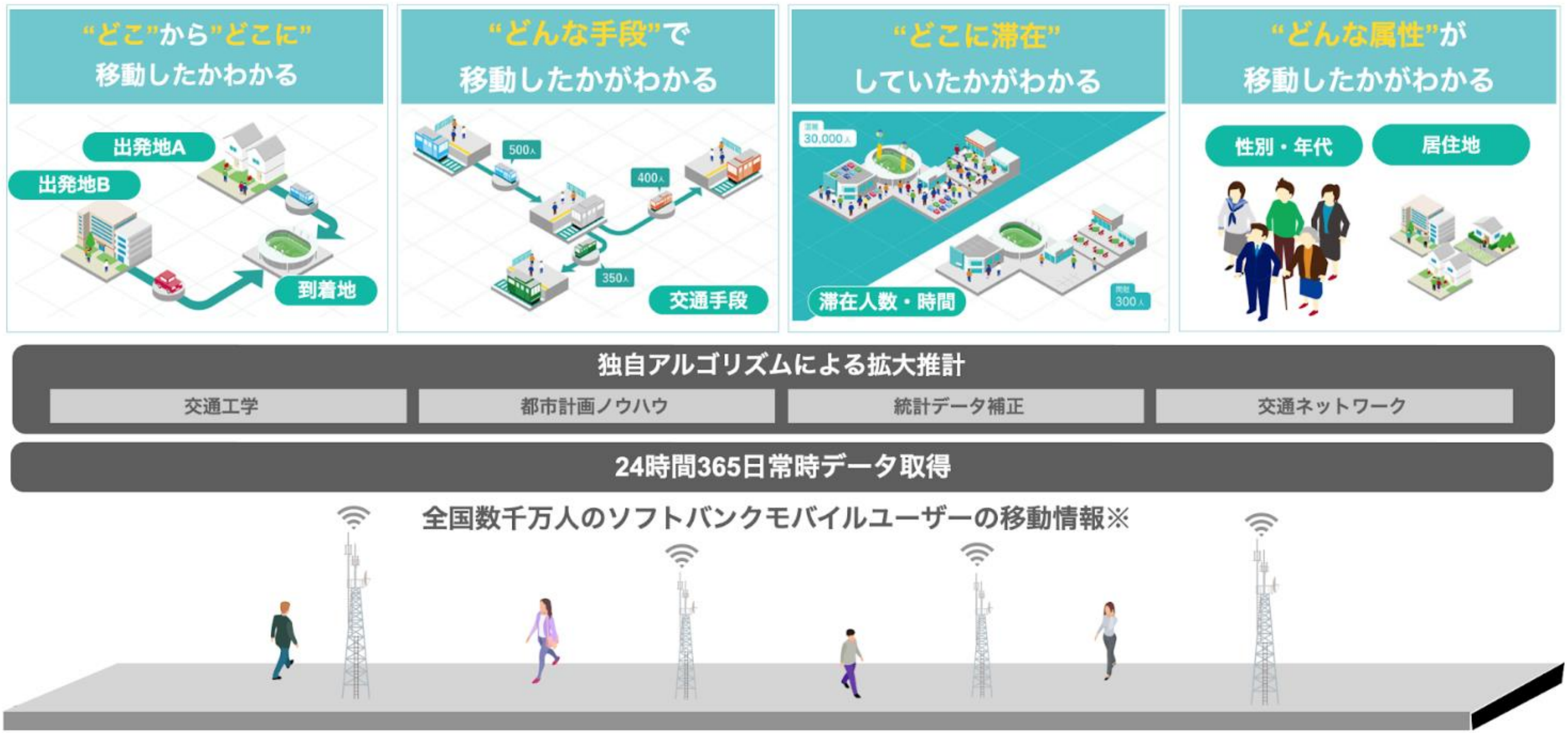
＊年齢のコードも17個

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

Toward the utilization of zenkoku-ugoki-tokei data

SoftBank: “Nationwide movement statistics data”

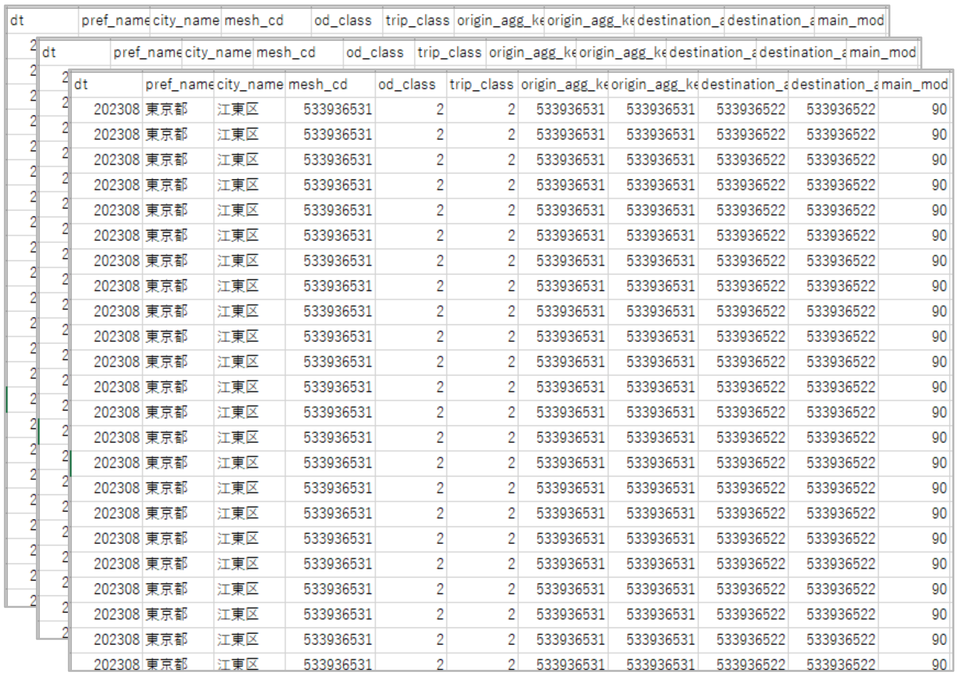
- Zenkoku-ugoki-tokei data, which utilizes location information obtained from base stations, provides statistical insights into people's movements and durations of stay.



※ After anonymization and statistical processing to ensure individuals cannot be identified, sensitive data from a small number of individuals will be protected through confidentiality procedures.

Data generation and future Plans

- We will establish effective data for implementing the Digital Sandbox and enhancing Pseudo-People-Flow data.



dt	pref_name	city_name	mesh_cd	od_class	trip_class	origin_agg_ke	origin_agg_ke	destination_a	destination_a	main_mod
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90
202308	東京都	江東区	533936531	2	2	533936531	533936531	533936522	533936522	90

Extracting the necessary data for subsequent tasks

Data development for implementation in the Digital Sandbox and for conducting social experiments

***Works since FY24 toward the selection of social experiment sites**

Organizing the characteristics and key features of the data for the advanced development of Pseudo-People-Flow

***Works for the selection of social experiment sites from FY24**

Result

＜Thesis＞

- Sun, C., Shibuya, Y., & Sekimoto, Y. (2024). Social segregation levels vary depending on activity space types: Comparison of segregation in residential, workplace, routine and non-routine activities in Tokyo metropolitan area. Cities, 146, 104745.

＜Result of non-public thesis＞

- Case studies of social experiment
（Road Bureau: 103cases, Cabinet Office: 113cases,
City Bureau: 41cases）

This paper includes the results of Cross-ministerial Strategic Innovation Promotion Program (SIP) 3rd Phase, “Development of Smart Mobility Platform” promoted by Council for Science, Technology and Innovation, Cabinet Office.（Project Management Agency : New Energy and Industrial Technology Development Organization (NEDO) (Project Code JPNP23023))