Snap4City SUMI Manager: A Digital Twin-Integrated Framework for Sustainable Urban Mobility Indicator Processing and Visualization

Stefano Bilotta[1], Enrico Collini[2], Marco Fanfani[2], Luciano Alessandro Ipsaro Palesi[2],Paolo Nesi[2], Gianni Pantaleo[2]

[1] DIMAI, University of Florence, Florence, Italy
[2] DISIT Lab, DINFO, University of Florence, Florence, Italy
https://www.disit.org, https://www.snap4city.org, https://digitaltwin.snap4city.org

A Growing Challenge for Modern Cities

City Population Density is rapidly increasing

Urban Population Growth
~ +1.5 – 3 %

City area expansion
~ + 0.2 – 0.5 %

Naples
~7.600–8.000 (residents/km²)

A Growing Challenge for Modern Cities

City Population Density is rapidly increasing

Mobility Stress

Urban Population Growth
~ +1.5 – 3 %

City area expansion
~ + 0.2 – 0.5 %

→

Traffic Congestion
→ Longer travel time

Environment Impact
→ Air and Noise pollution

Safety
→ Road Accidents

tomtom | Traffic Index

Cities City | Metro

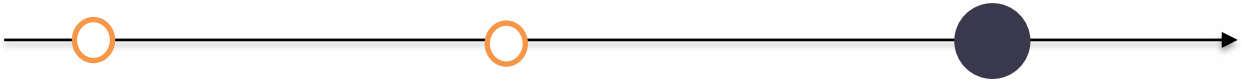
5	Florence	45.0%	↑ + 0.3 pp	113 hours
6	Naples	44.5%	↓ -0.6 pp	90 hours

A Growing Challenge for Modern Cities

City Population Density is rapidly increasing

Mobility Stress

Interventions



Urban Population Growth
~ +1.5 – 3 %

City area expansion
~ + 0.2 – 0.5 %

→

Traffic Congestion
→ Longer travel time

Environment Impact
→ Air and Noise pollution

Safety
→ Road Accidents

→

Active Mobility
→ Sharing, Corridors

Optimization
→ Road Infrastructure and TP

Constraints
→ Mobility limits

Sensors & Digitization
→ Mobility Digital Twin

A Growing Challenge for Modern Cities

City Population Density is rapidly increasing

Mobility Stress

Interventions

Validation

Urban Population Growth
~ +1.5 – 3 %

City area expansion
~ + 0.2 – 0.5 %

→

Traffic Congestion
→ Longer travel time

Environment Impact
→ Air and Noise pollution

Safety
→ Road Accidents

→

Active Mobility
→ Sharing, Corridors

Optimization
→ Road Infrastructure and TP

Constraints
→ Mobility limits

Sensors & Digitization
→ Mobility Digital Twin

→

How to monitor interventions outcomes?

Data-Driven KPIs

Data-Driven Urban Mobility solution

Should:

- **Support** evidence-based urban mobility **planning**
- Enable **comparisons** between **cities** and over **time**
- **Multi-sector** covering environmental, social, and economic aspects of mobility

Problems:

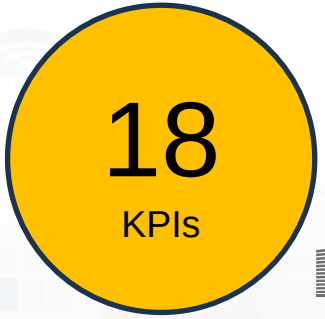
- **Data collection** can be challenging
- Heterogeneous data sources **integration**
- Need for Big-Data management **platform** for historical and cross city evaluation
- Difficulty in ensuring cross-city **comparisons**

Standard KPIs to:
Compare Cities – Track Progress

Big Data Platform to:
Enable decision support

EU Indicators

To establish comparability across member states, the European Commission introduced the **Sustainable Urban Mobility Indicators (SUMI)**.



European Commission

- Social equity & transport accessibility
- Environmental emissions, noise, energy footprint
- Operational safety, health, accessibility, space

Affordability of Public Transport (S1)

Share of the household budget of the poorest quartile (25%) of the population required to purchase public transport passes (unlimited monthly travel or equivalent) in the urban area of residence.

First 10 SUMI data sources

ID	Indicator	Area	Output Metric	**Required Data Type**
S1	Affordability of PT for poorest group	Social	% household budget	**Household income statistics, public transport fare data, socio-economic statistics**
S2	Accessibility for mobility-impaired users	Social	% services facilitated	**GTFS, GIS network data, accessibility infrastructure inventory, public transport asset data**
S3	Air pollutant emissions (NOx, PM2.5)	Environment	EHI (kg PM2.5 eq./cap/yr)	**Traffic and mobility data, vehicle fleet data, emission factors, population statistics**
S4	Noise hindrance	Environment	% hindered population	**Noise maps (GIS), traffic data, population distribution (GIS/Census)**
S5	Road deaths	Safety	Fatality rate per 100k inh.	**Road crash database, mortality statistics, population statistics**
S6	Access to mobility services	Social	Appropriate Access Index (%)	**GIS land-use data, GTFS, mobility service locations, population distribution**
S7	Greenhouse gas emissions	Environment	t CO_2 eq./cap/yr	**Travel demand data, vehicle fleet data, energy consumption, emission factors, population statistics**
S8	Congestion & delays	Performance	% delay during peak hour	**Traffic data, floating car data, GPS data, travel time data**
S9	Energy efficiency	Environment	MJ/km	**Energy consumption data, vehicle operation data, travel distance data**
S10	Opportunity for active mobility	Safety	% road length adapted	**GIS street network, cycling and walking infrastructure data**

SUMI Manager Architecture

Multi-Domain Integration

Managing different data sources: socio-economic statistics, real-time public transport GTFS data, GIS urban network, population data

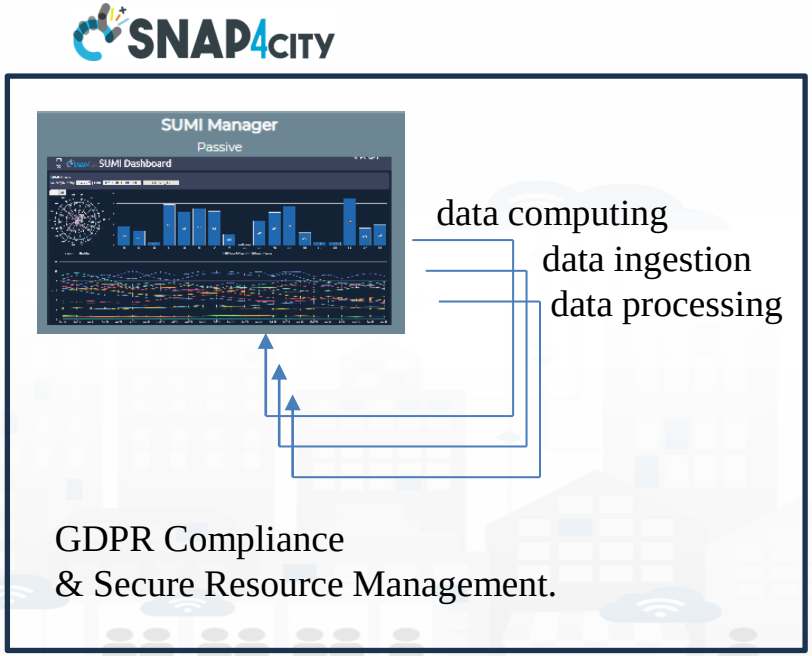
Spatio-Temporal Sync

Cross-City and time-series data management to ensure comparability.

Firenze, Pisa – system validation

Urban Mobility Digital Twin

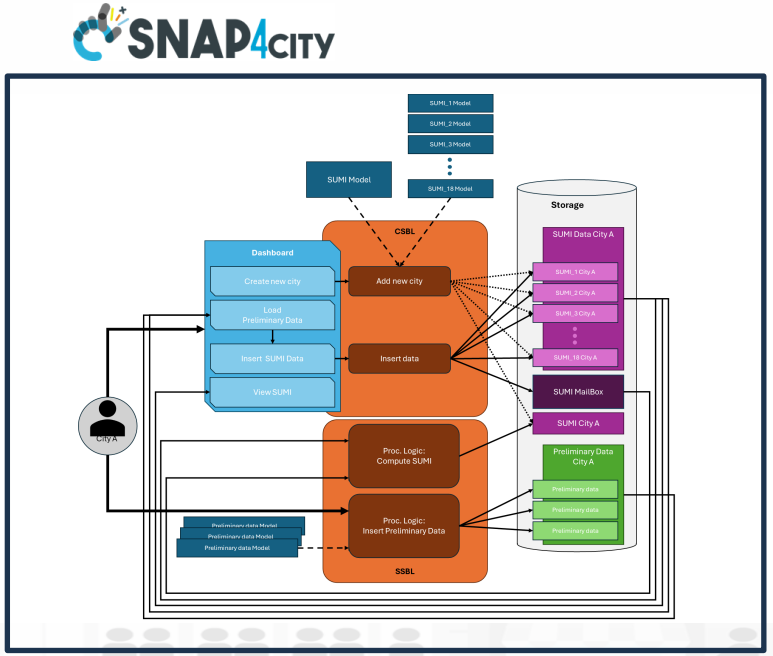
Built on Snap4City: real-time data streams, knowledge base, ontology (KM4City), reproducible models

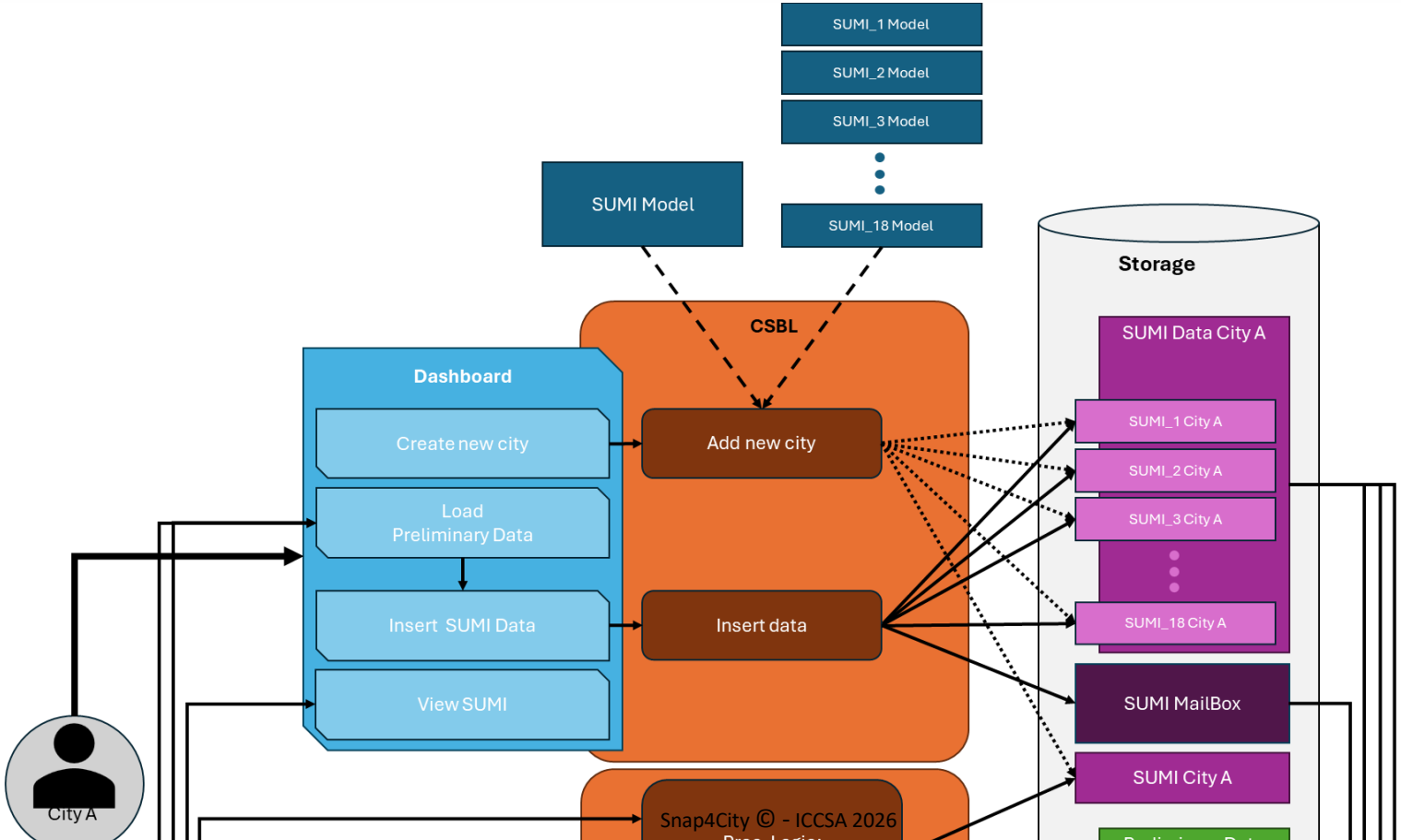


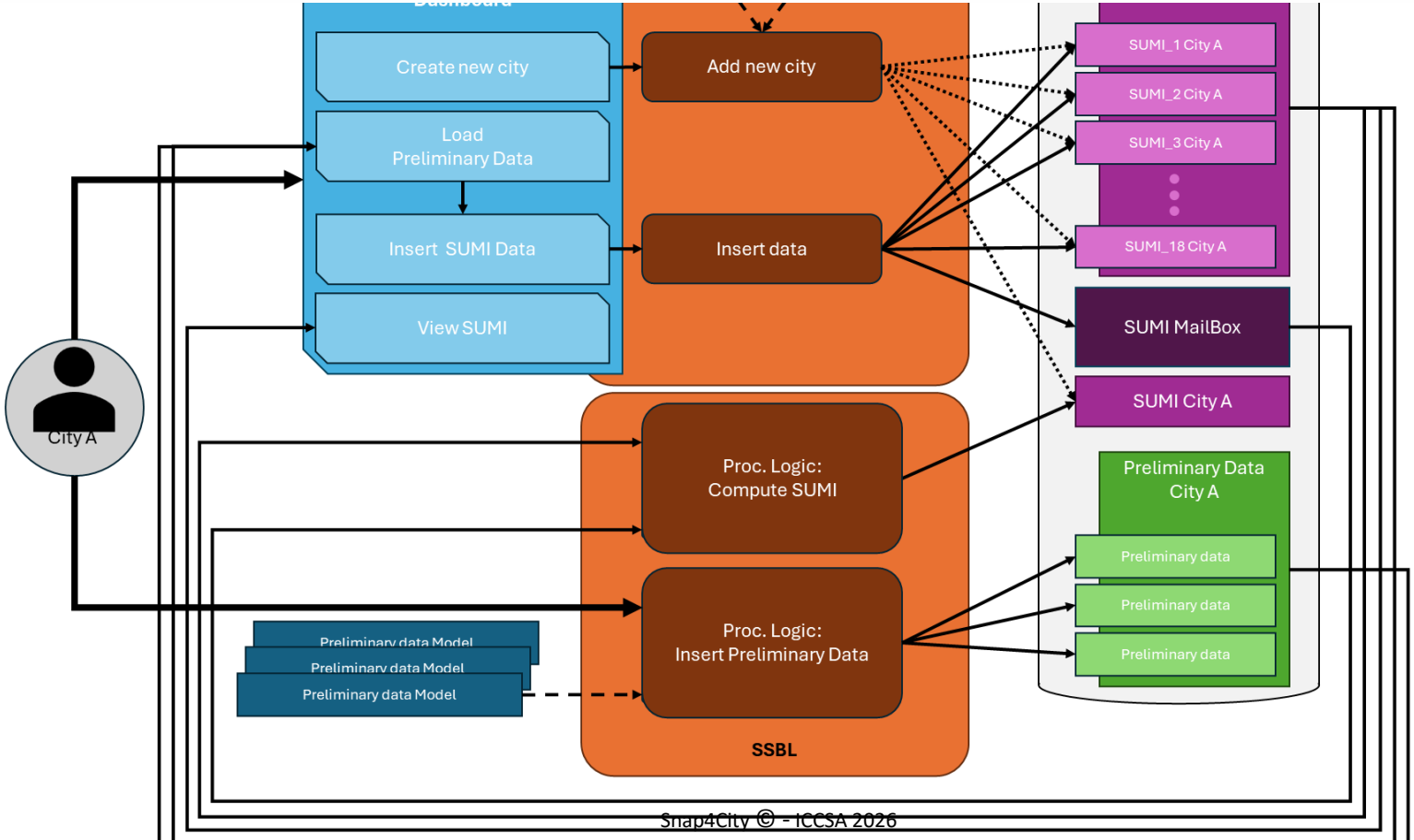
SUMI Manager Architecture

SUMI Calculation Lifecycle

1. City Creation
2. Data Input
3. Trigger Computing
4. Rendering & Comparison




SUMI_1 Model
SUMI_2 Model
SUMI_3 Model
SUMI_18 Model
SUMI Model
Storage
CSBL
Dashboard
Create new city
Add new city
Load Preliminary Data
Insert SUMI Data
Insert data
View SUMI
SUMI Data City A
SUMI_1 City A
SUMI_2 City A
SUMI_3 City A
SUMI_18 City A
SUMI MailBox
SUMI City A
City A
Snap4City © - ICCSA 2026


Create new city
Load Preliminary Data
Insert SUMI Data
View SUMI
Add new city
Insert data
SUMI_1 City A
SUMI_2 City A
SUMI_3 City A
SUMI_18 City A
SUMI MailBox
SUMI City A
City A
Proc. Logic: Compute SUMI
Proc. Logic: Insert Preliminary Data
Preliminary data Model
Preliminary data Model
Preliminary data Model
SSBL
Preliminary Data City A
Preliminary data
Preliminary data
Preliminary data

SUMI Dashboard and System Validation

Select City

City SUMI Radar Chart

Add New City

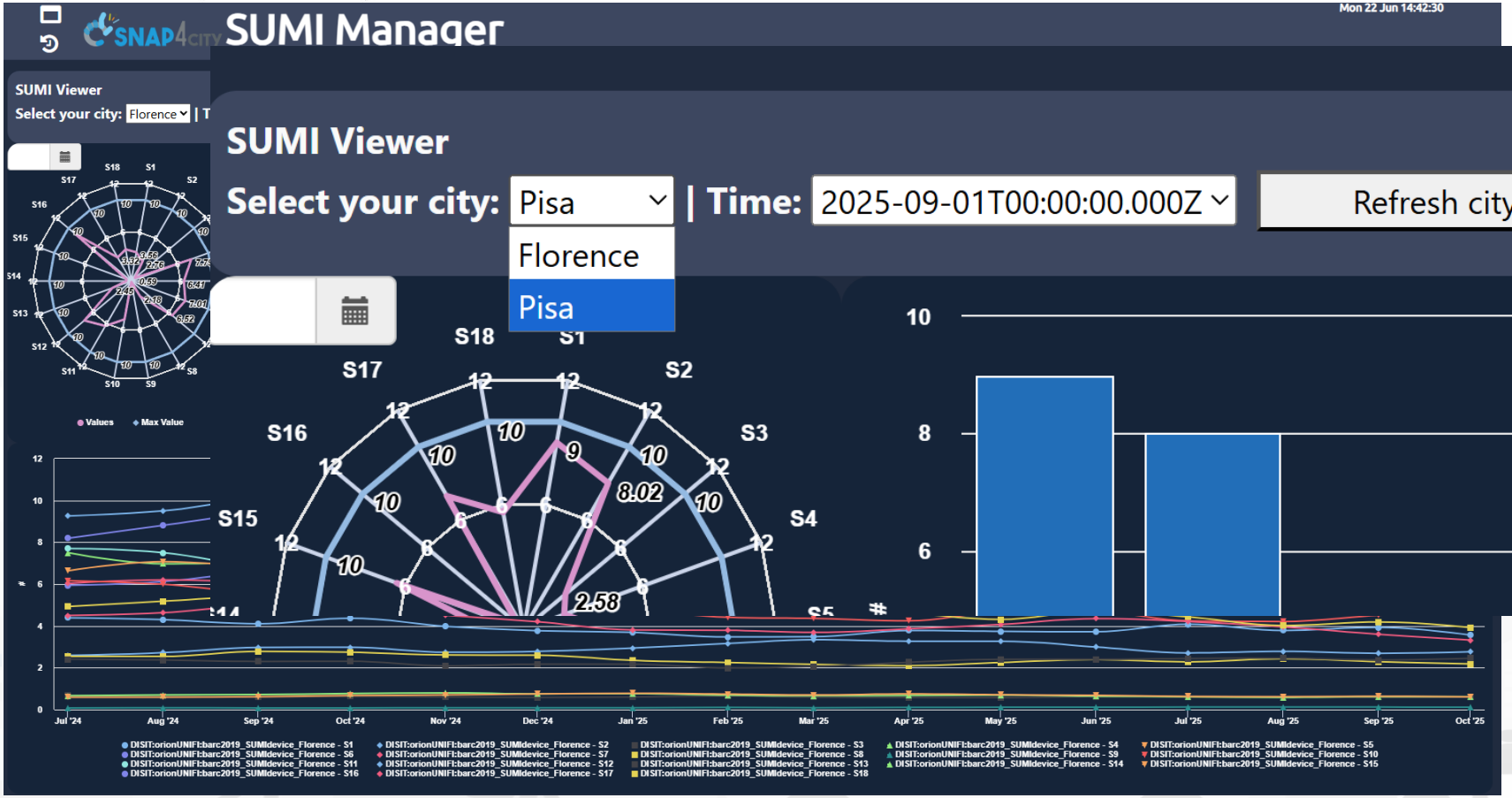
City SUMI Bar Plot

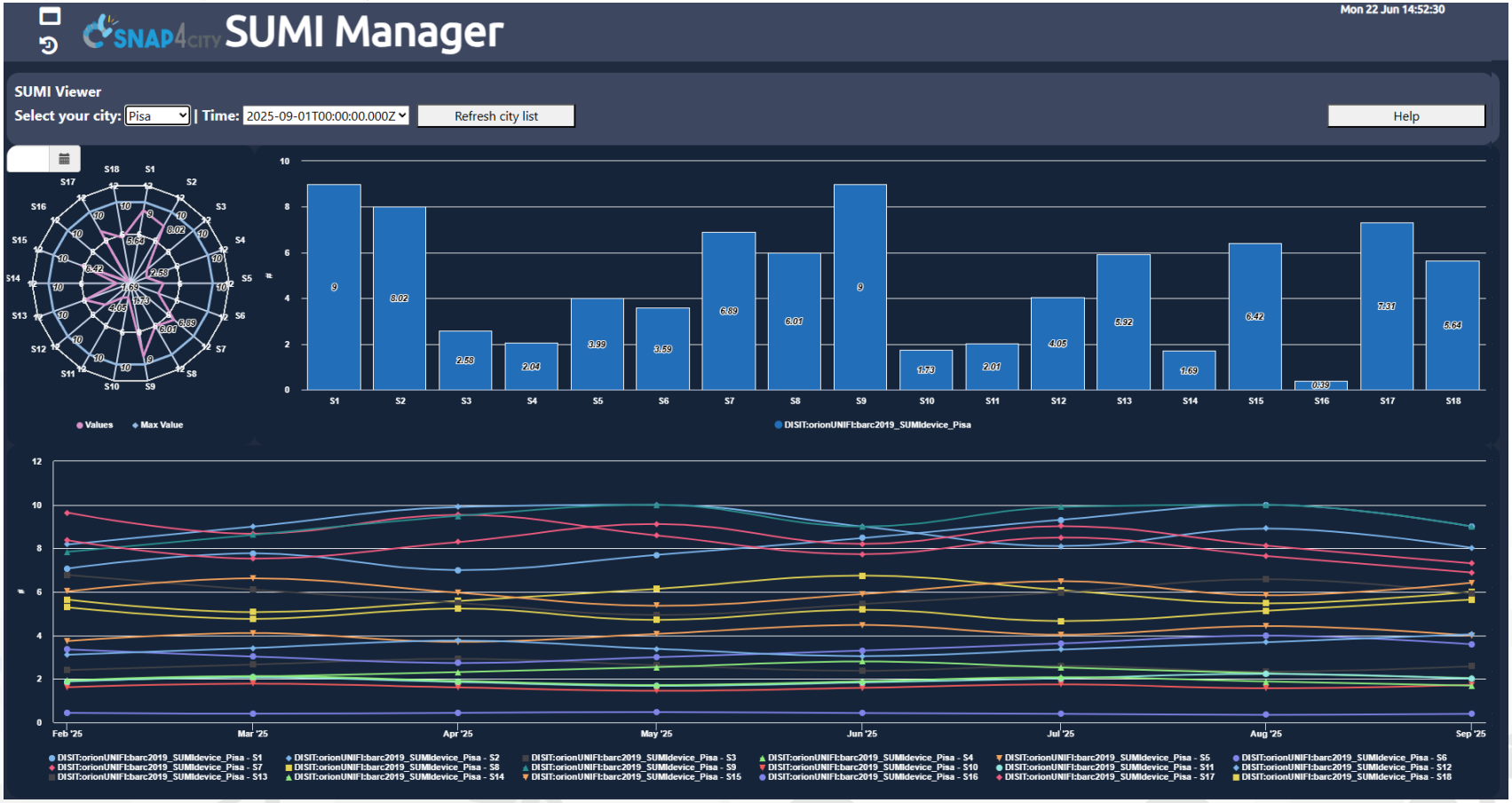
City SUMI Time-Trend

FE computing

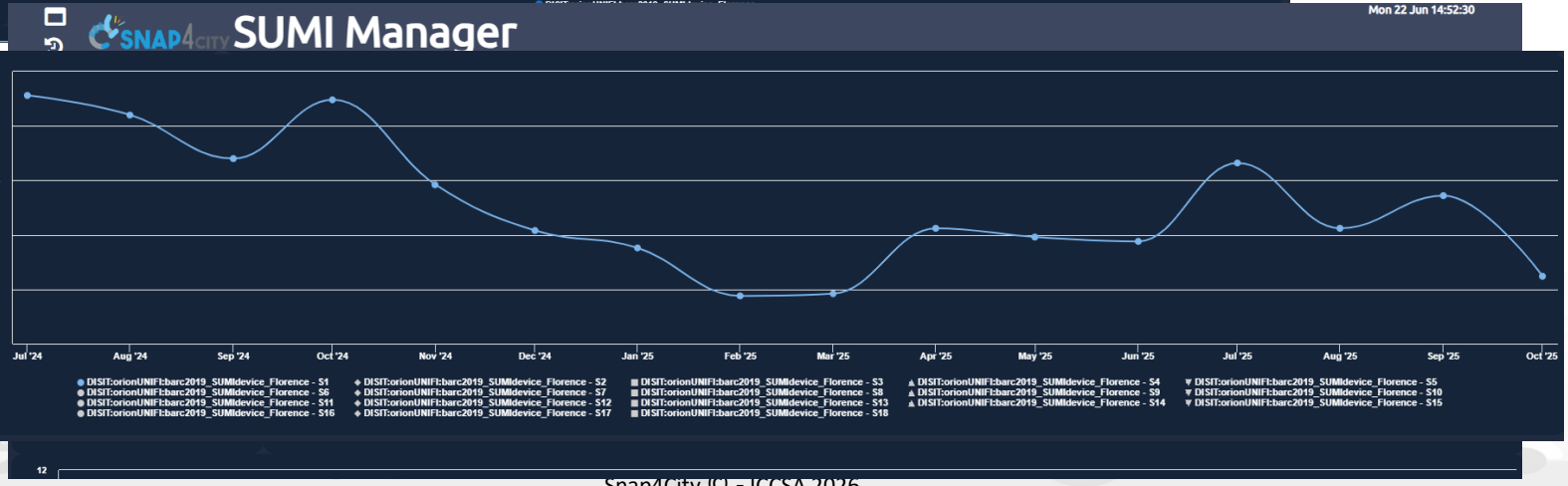
direct

computed


SUMI Manager
Mon 22 Jun 14:42:30
SUMI Viewer
Select your city: Florence | T
SUMI Viewer
Select your city: Pisa | Time: 2025-09-01T00:00:00.000Z
Refresh city list
Florence
Pisa
Values
Max Value
S18
S1
S2
S3
S4
S5
S6
S7
S8
S9
S10
S11
S12
S13
S14
S15
S16
S17
8.02
2.58
Jul '24
Aug '24
Sep '24
Oct '24
Nov '24
Dec '24
Jan '25
Feb '25
Mar '25
Apr '25
May '25
Jun '25
Jul '25
Aug '25
Sep '25
Oct '25
DISIT:orionUNIFI:barc2019_SUMIdevice_Florence - S1
DISIT:orionUNIFI:barc2019_SUMIdevice_Florence - S2
DISIT:orionUNIFI:barc2019_SUMIdevice_Florence - S3
DISIT:orionUNIFI:barc2019_SUMIdevice_Florence - S4
DISIT:orionUNIFI:barc2019_SUMIdevice_Florence - S5
DISIT:orionUNIFI:barc2019_SUMIdevice_Florence - S6
DISIT:orionUNIFI:barc2019_SUMIdevice_Florence - S7
DISIT:orionUNIFI:barc2019_SUMIdevice_Florence - S8
DISIT:orionUNIFI:barc2019_SUMIdevice_Florence - S9
DISIT:orionUNIFI:barc2019_SUMIdevice_Florence - S10
DISIT:orionUNIFI:barc2019_SUMIdevice_Florence - S11
DISIT:orionUNIFI:barc2019_SUMIdevice_Florence - S12
DISIT:orionUNIFI:barc2019_SUMIdevice_Florence - S13
DISIT:orionUNIFI:barc2019_SUMIdevice_Florence - S14
DISIT:orionUNIFI:barc2019_SUMIdevice_Florence - S15
DISIT:orionUNIFI:barc2019_SUMIdevice_Florence - S16
DISIT:orionUNIFI:barc2019_SUMIdevice_Florence - S17
DISIT:orionUNIFI:barc2019_SUMIdevice_Florence - S18

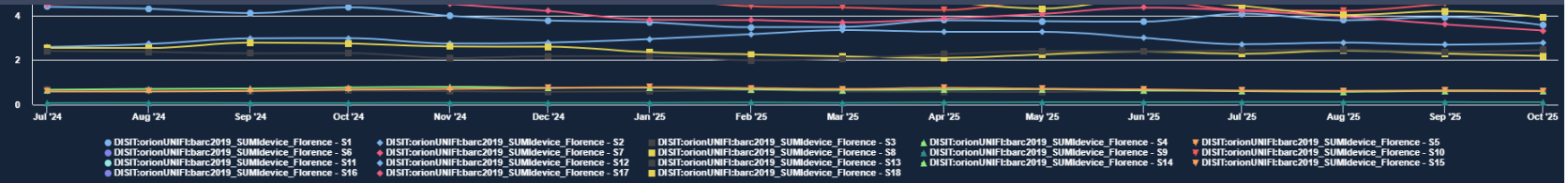

SNAP4CITY SUMI Manager
Mon 22 Jun 14:52:30
SUMI Viewer
Select your city: Pisa | Time: 2025-09-01T00:00:00.000Z
Refresh city list
Help
Values
Max Value
DISIT:orionUNIFI:barc2019_SUMIdevice_Pisa
Feb '25
Mar '25
Apr '25
May '25
Jun '25
Jul '25
Aug '25
Sep '25


SUMI Manager
Mon 22 Jun 14:42:30
SUMI Viewer
Select your city: Florence | Time: 2025-10-01T00:00:00.000Z
Refresh city list
Help
Values
Max Value


SUMI Manager
Mon 22 Jun 14:52:30

SUMI Manager

Mon 22 Jun 14:49:07



SUMI Data Loading

Add a new city Ex. Florence Submit

S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15 S16 S17 S18

Select Indicator S1 Mode Calculate from data Validity startdate 03/06/2026 Validity end date 03/07/2026 City select Florence Refresh citylist

Average monthly income of the poorest 25% of the population:

Average household size of the poorest 25% of the population:

Monthly urban public transport pass price:

Submit

S1 Select Indicator S1 Mode Calculate from data Validity startdate 03/06/2026 Validity end date 03/07/2026 City select Florence

S2

S3 Average monthly income of the poorest 25% of the population:

S4

S5 Average household size of the poorest 25% of the population:

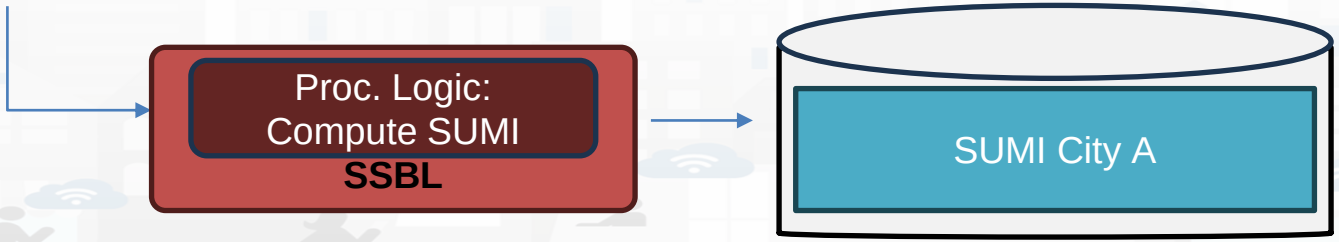
S6

S7 Monthly urban public transport pass price:

S8

S9

S10 Submit



Conclusions

Gap Addressed

First integrated tool enabling automatic computation of all 18 SUMI indicators for public administrations

Multi-City Support

Compare SUMI across cities and over time with interactive temporal dashboards

Standards-Compliant

Aligned with SUMI Harmonization Guidelines, EU Urban Mobility Framework, European Green Deal

Multi-Ingestion Modes

Gradual adoption: manual entry → input-variable computation → automatic pre-fill from external data sources

Urban Mobility Digital Twin

Built on Snap4City: real-time data streams, knowledge base, ontology (KM4City), reproducible models

Privacy & Governance

Multi-tenant, GDPR-compliant with role-based delegation (sumi_admin / sumi_user)

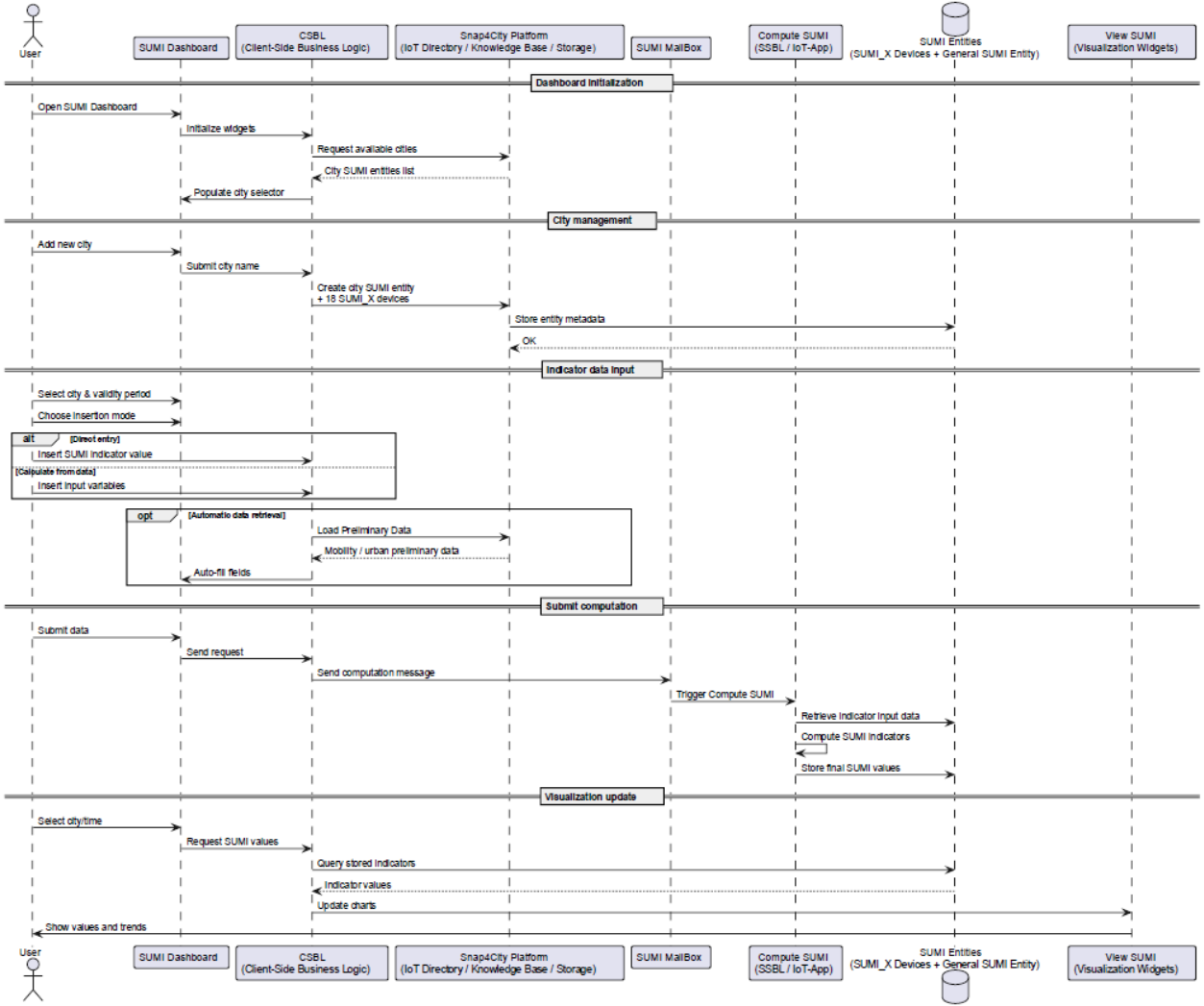
Thank you for your attention

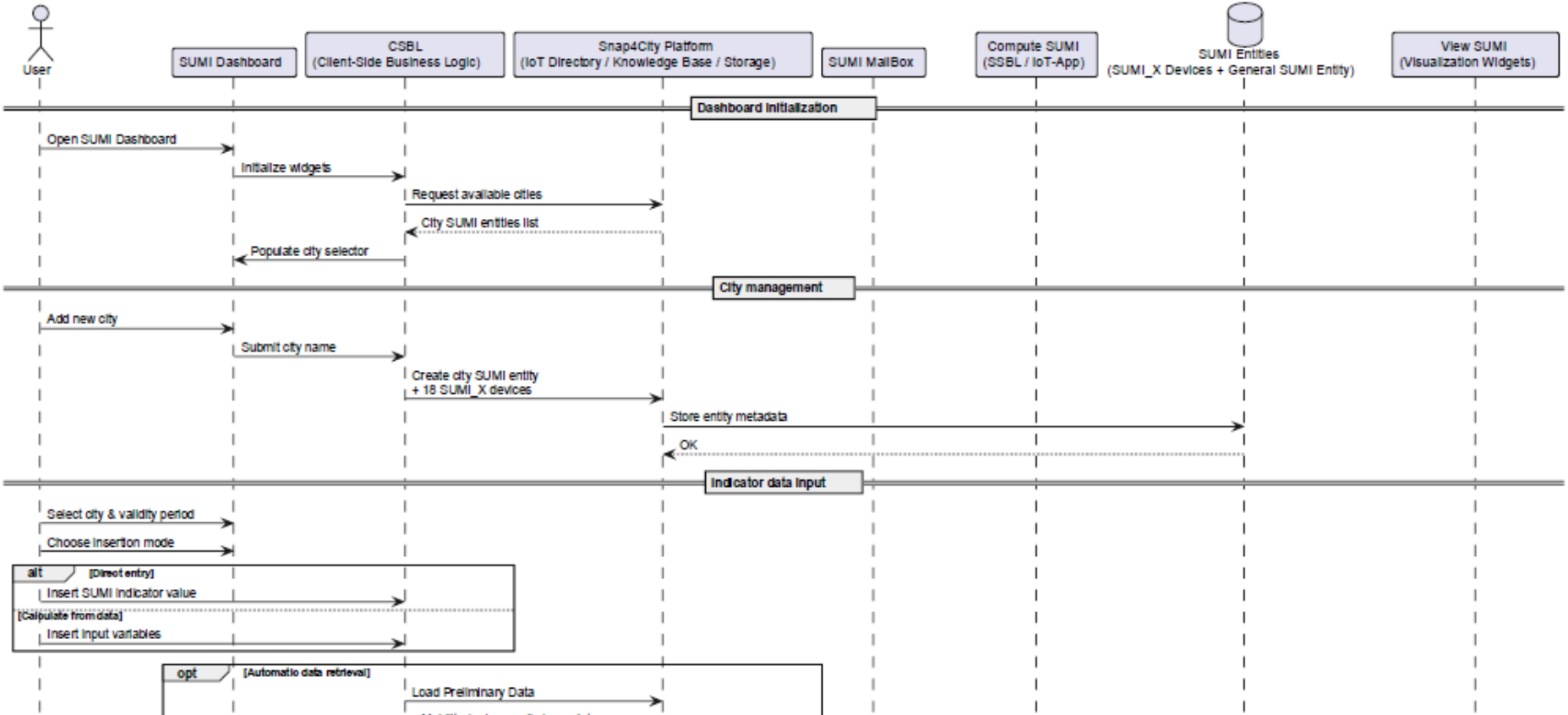
Enrico Collini| DISIT Lab, University of Florence
https://www.snap4city.org | https://www.disit.org

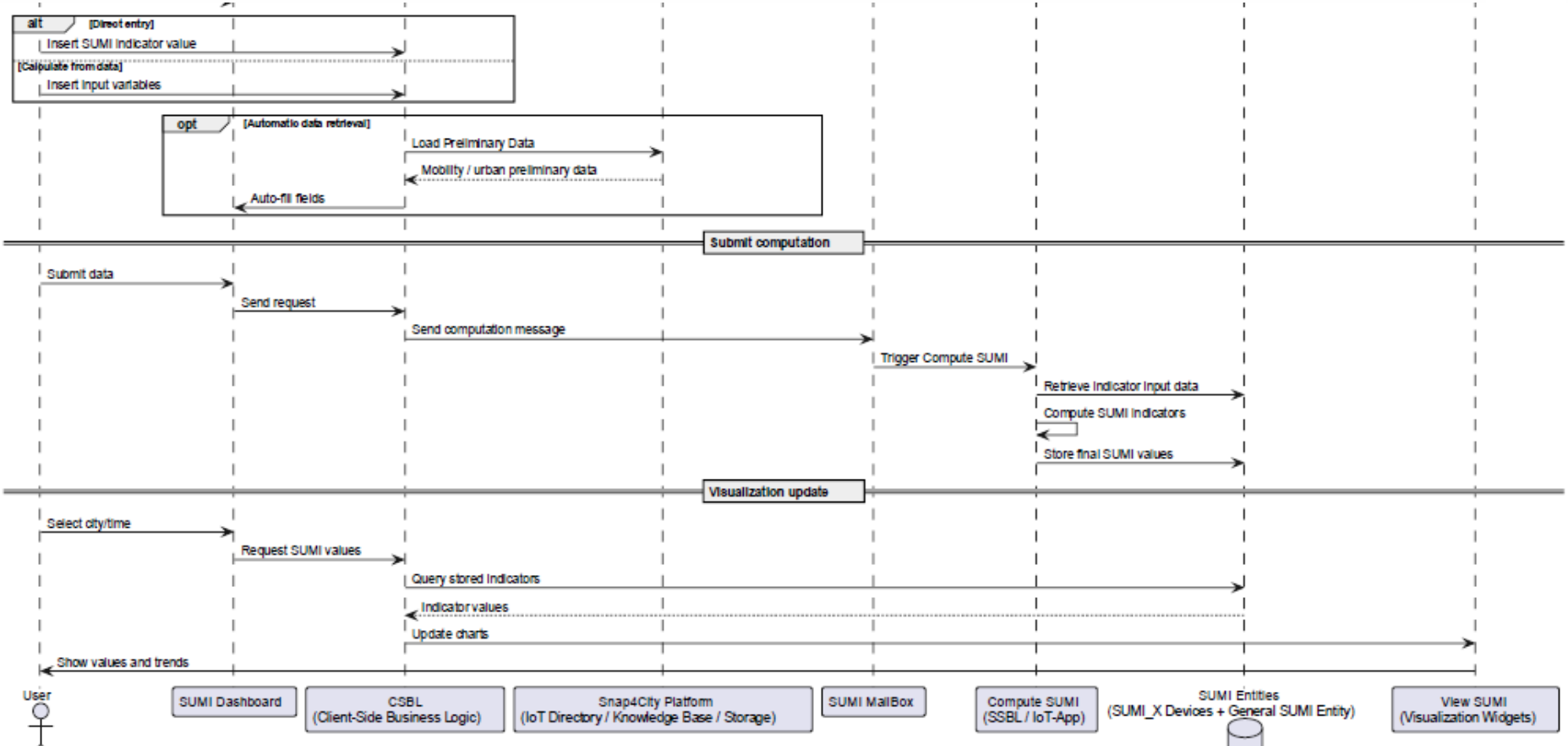
Appendix

Data Model Specifications

Data Model	Application Description	Key Fields / Variables	Primary Purpose
Single SUMI (S1 - S18)	Defined individually for each of the 18 indicators	Computation variables (e.g., avgIncome, ptPrice) + timestamp	Storage of primary calculation variables
General SUMI Model	Aggregates all computed city indicators	dateObserved + 18 computed variables (one per indicator)	Historical analysis and cross-indicator trend visualization
Context Data Model	Pre-existing territorial datasets on the platform	PT stops, bike sharing stations, registries, average income	Automated ingestion (Preliminary Data Ingestion)


User
SUMI Dashboard
CSBL (Client-Side Business Logic)
Snap4City Platform (IoT Directory / Knowledge Base / Storage)
SUMI MailBox
Compute SUMI (SSBL / IoT-App)
SUMI Entities (SUMI_X Devices + General SUMI Entity)
View SUMI (Visualization Widgets)
Dashboard initialization
Open SUMI Dashboard
Initialize widgets
Request available cities
City SUMI entities list
Populate city selector
City management
Add new city
Submit city name
Create city SUMI entity + 18 SUMI_X devices
Store entity metadata
OK
Indicator data input
Select city & validity period
Choose insertion mode
alt
[Direct entry]
Insert SUMI indicator value
[Calculate from data]
Insert input variables
opt
[Automatic data retrieval]
Load Preliminary Data
Mobility / urban preliminary data
Auto-fill fields
Submit computation
Submit data
Send request
Send computation message
Trigger Compute SUMI
Retrieve indicator input data
Compute SUMI indicators
Store final SUMI values
Visualization update
Select city/time
Request SUMI values
Query stored indicators
Indicator values
Update charts
Show values and trends


User
SUMI Dashboard
CSBL (Client-Side Business Logic)
Snap4City Platform (IoT Directory / Knowledge Base / Storage)
SUMI MailBox
Compute SUMI (SSBL / IoT-App)
SUMI Entities (SUMI_X Devices + General SUMI Entity)
View SUMI (Visualization Widgets)
Dashboard initialization
Open SUMI Dashboard
Initialize widgets
Request available cities
City SUMI entities list
Populate city selector
City management
Add new city
Submit city name
Create city SUMI entity + 18 SUMI_X devices
Store entity metadata
OK
Indicator data input
Select city & validity period
Choose insertion mode
alt
[Direct entry]
Insert SUMI indicator value
[Calculate from data]
Insert input variables
opt
[Automatic data retrieval]
Load Preliminary Data


alt
[Direct entry]
Insert SUMI indicator value
[Calculate from data]
Insert input variables
opt
[Automatic data retrieval]
Load Preliminary Data
Mobility / urban preliminary data
Auto-fill fields
Submit computation
Submit data
Send request
Send computation message
Trigger Compute SUMI
Retrieve indicator input data
Compute SUMI indicators
Store final SUMI values
Visualization update
Select city/time
Request SUMI values
Query stored indicators
Indicator values
Update charts
Show values and trends
User
SUMI Dashboard
CSBL
(Client-Side Business Logic)
Snap4City Platform
(IoT Directory / Knowledge Base / Storage)
SUMI MailBox
Compute SUMI
(SSBL / IoT-App)
SUMI Entities
(SUMI_X Devices + General SUMI Entity)
View SUMI
(Visualization Widgets)