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Smart City Digital Twin Platform Architecture for Mobility and Transport Decision Support Systems

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Motivation

- Due to increasing population living in highly-dense cities, **urban mobility is on of the most critical challenges** cities have to face
- For example, **traffic congestion** and **inadequate public transports** lead to several problems:
  - Increased travel times
  - Reduced productivity
  - Increased pollution
  - Social exclusion
  - ...
- There is the need of **tools** to **monitor** the city status and **provide support** to decision-makers in planning the urban development

Current solutions

- Current solutions for mobility studies (e.g., SUMO, PTV) are not sufficient:
  - Lack of automatic integration of **real-time data**
  - Do not provide **internal storage and (semantic) indexing** solutions for data
  - Require **on-premises installations** instead of more accessible web-based interfaces
  - Are limited in terms of data analytics for **predictions** and automated **generation of suggestions**
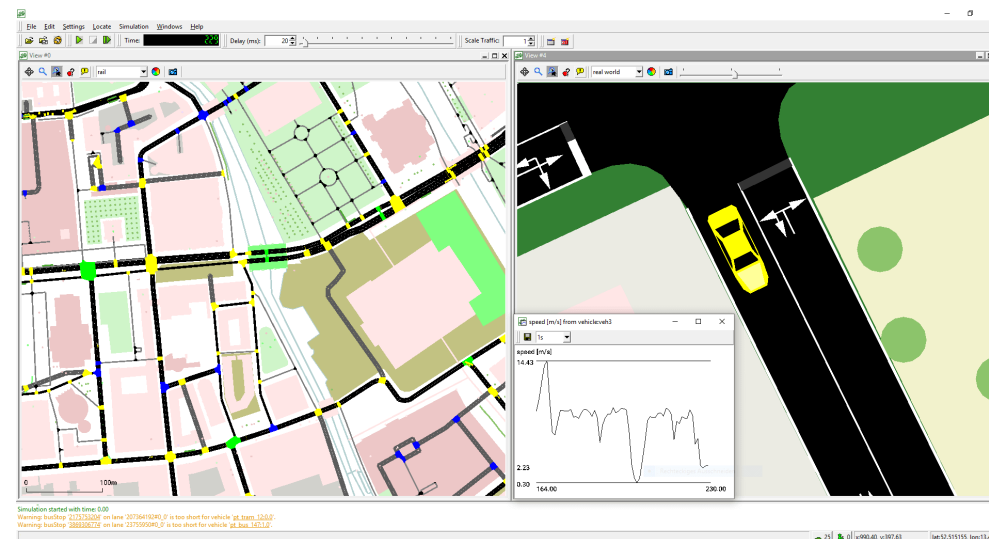
Smart City Digital Twin

- Urban digital twins, **continuously updated replicas of the real city**, can offer a better solution
  - Acquire and store **static**, **real-time**, and **historic** data
  - **Sematic indexing** of entities
  - APIs to retrieve data with **relational**, **geographic**, **temporal**, and **semantic** queries
  - Can integrate **a large set of analytics**
  - Can be used to perform **monitoring**, **what-if analysis**, generation of suggestion based on **automatic optimization**
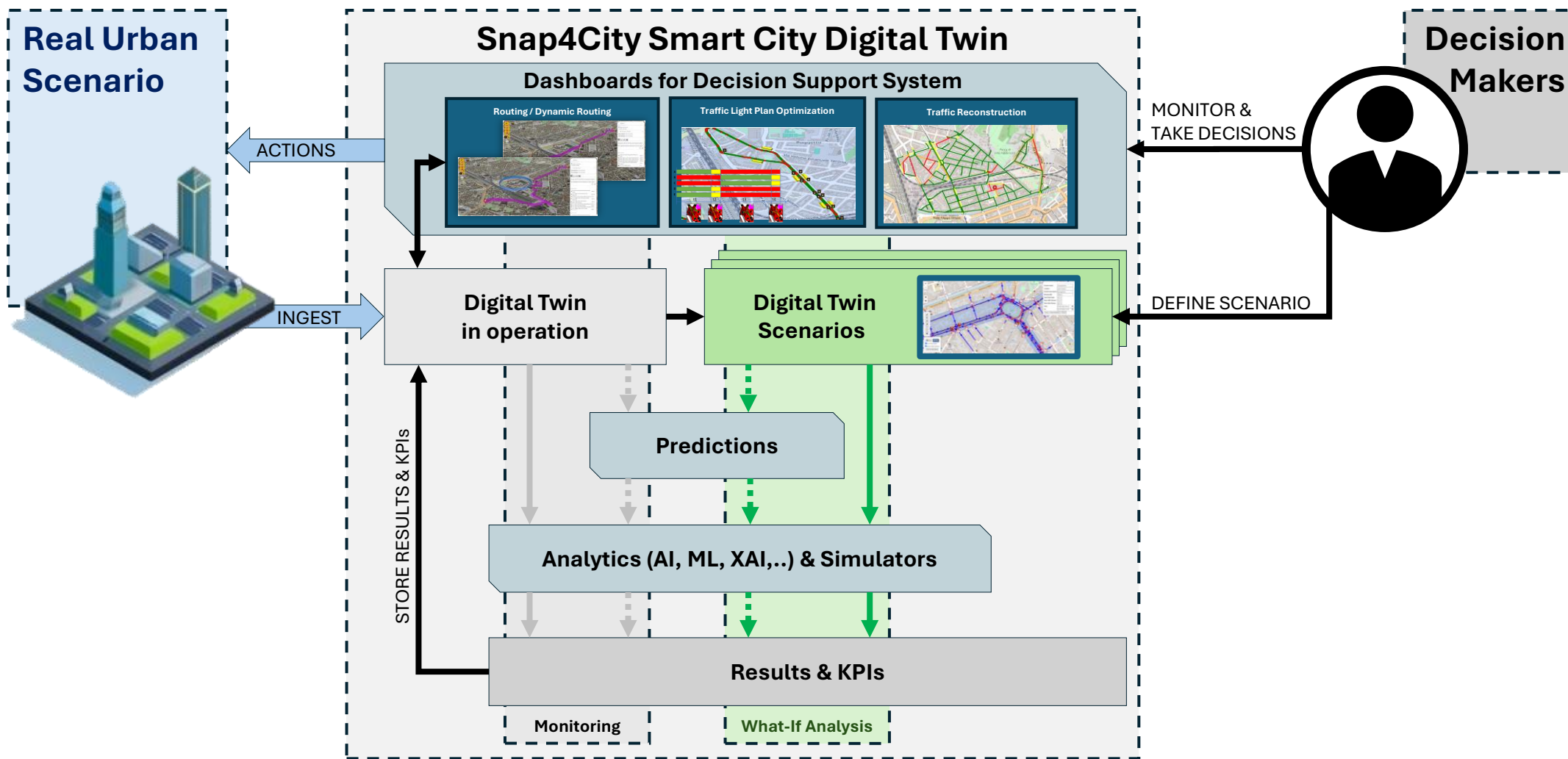

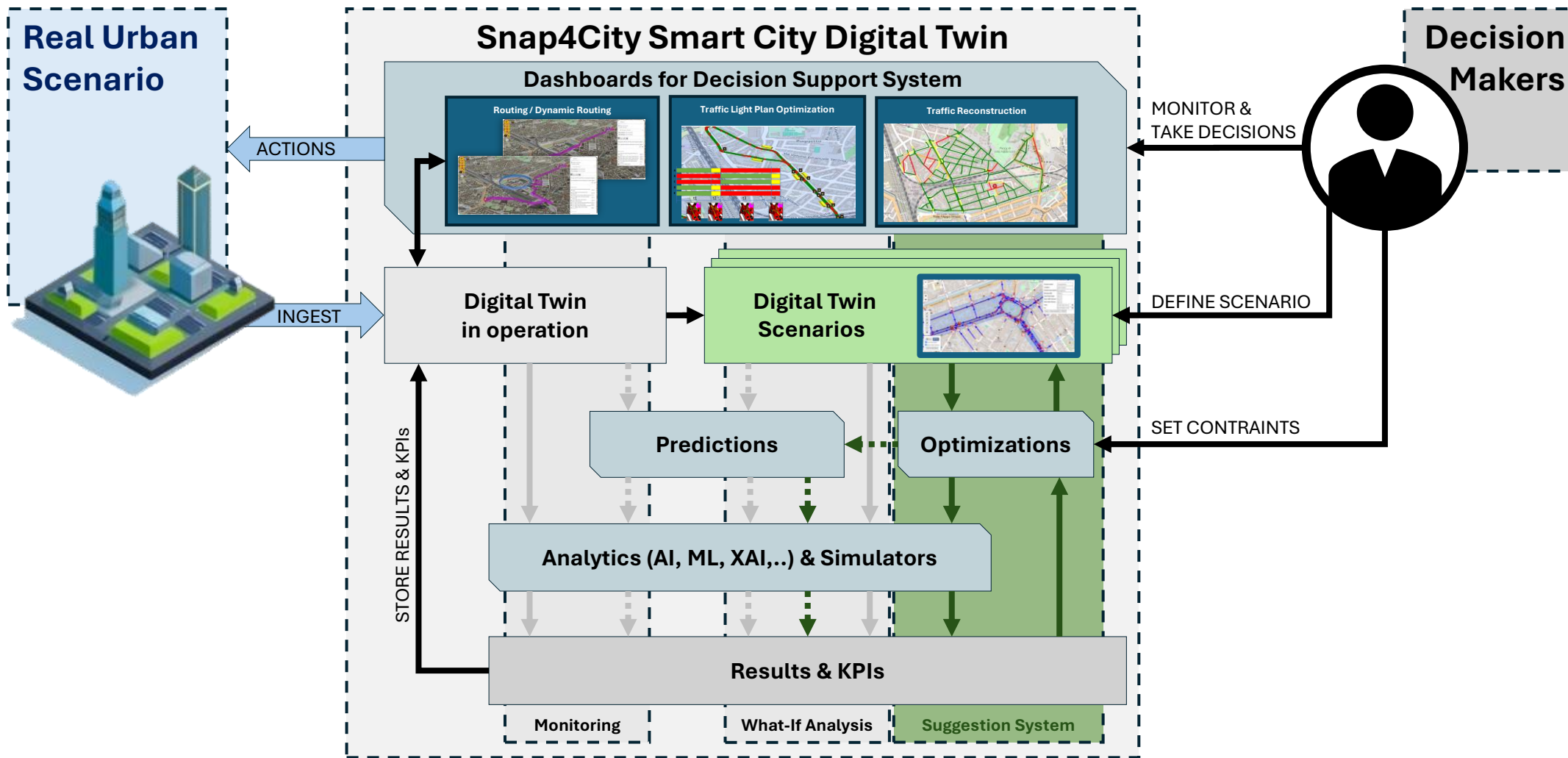https://digitaltwin.snap4city.org/

Snap4City Platform
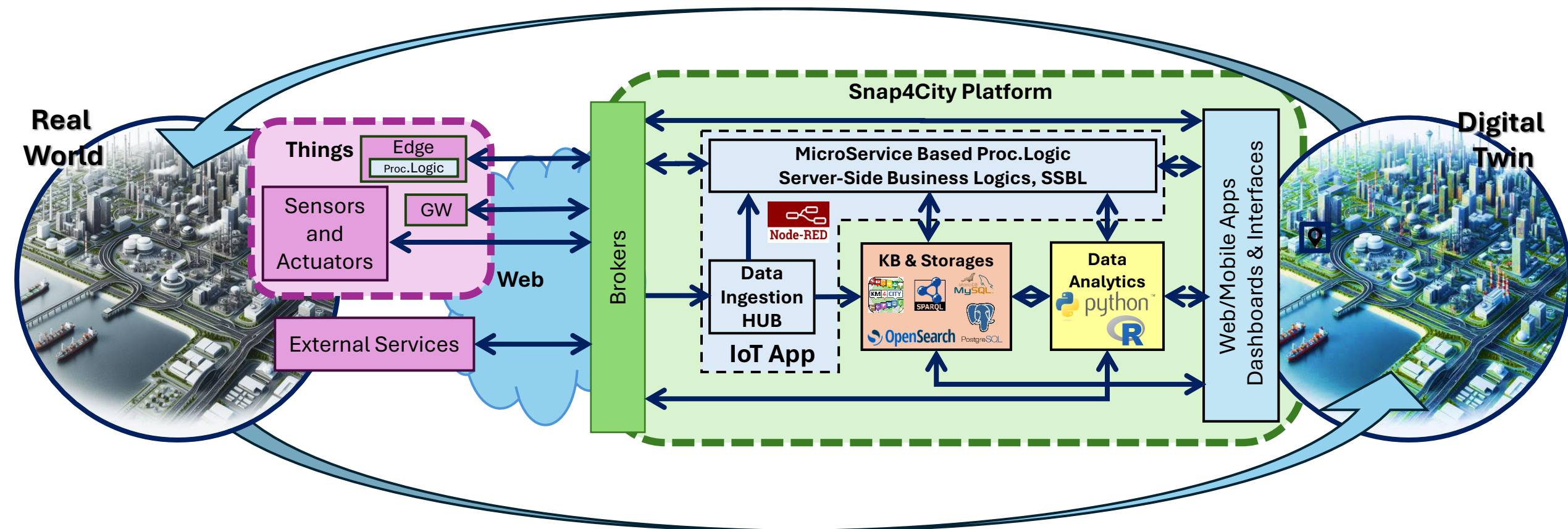
Workflow overview – Monitoring
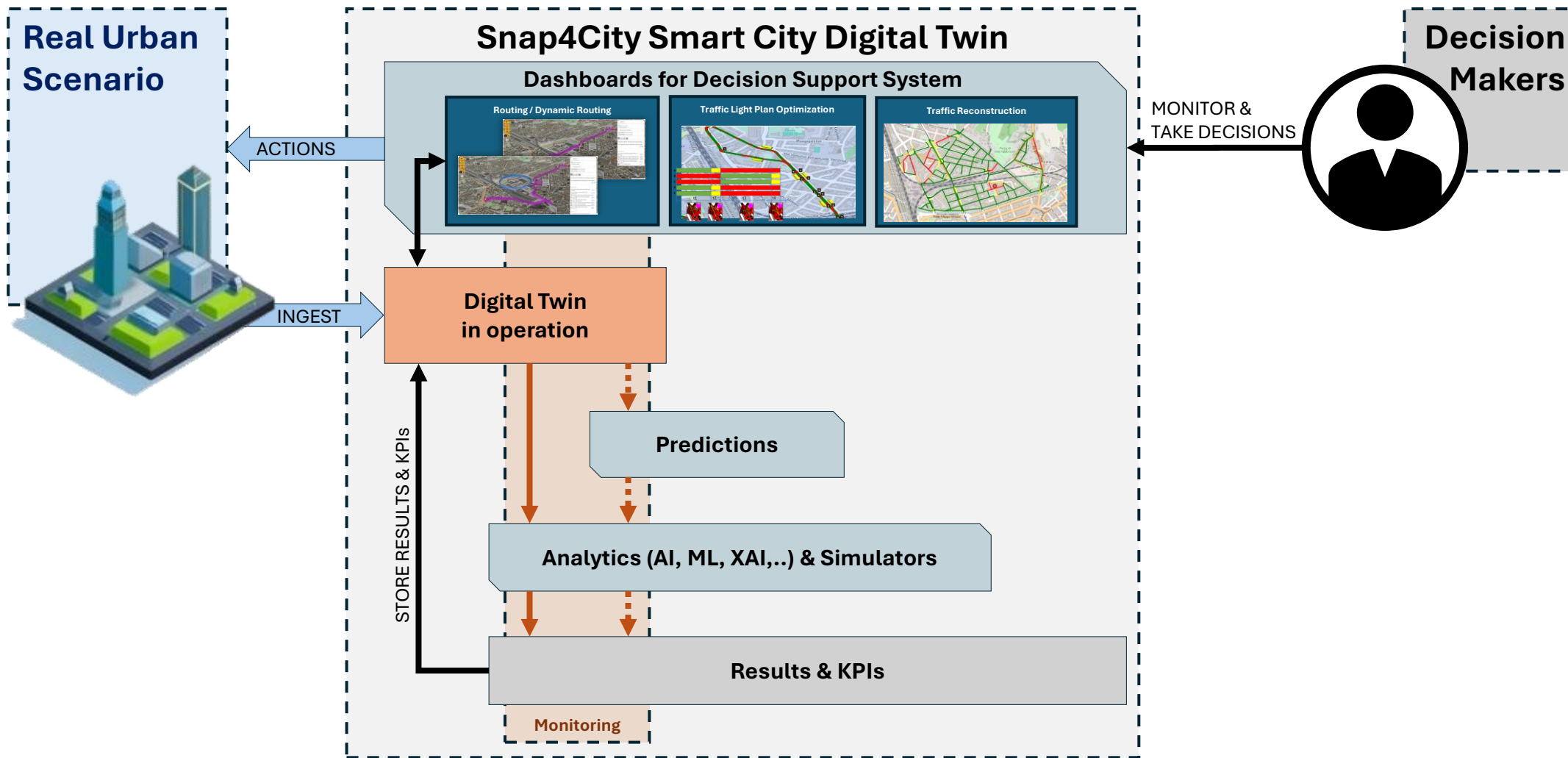
Workflow overview – What-if analysis

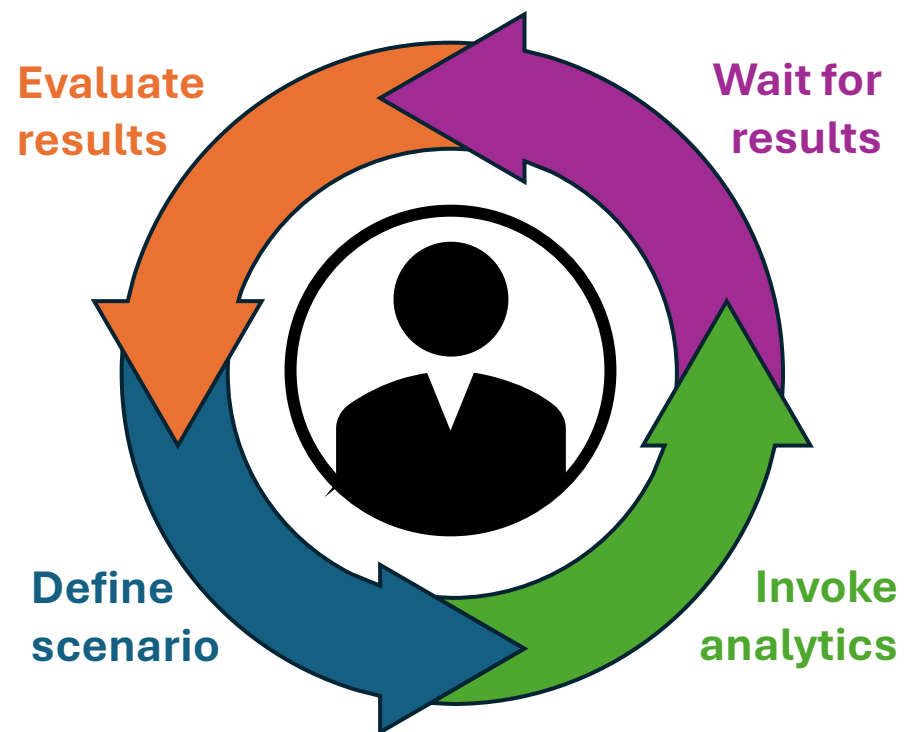# Workflow overview – Optimization

Human-in-the-loop

- During **what-if analysis,** the operator must

  1. Define scenario, applying changes
  2. Invoke analytics
 3. Wait for results and KPI
  4. Evaluate the results

- ... and **repeat the cycle** until a good solution is found

- **High time investment!**

Human-in-the-loop

- In the **optimization** case, the operator defines the **scenario**, the **goal**, some **constraints**

- The system **autonomously finds a set of solutions** from which the operator choose the best one

- **Benefits**:
  - Reduced human effort
  - Wider solution space exploration

Get a set of solutions

Define scenario, goal, constraints
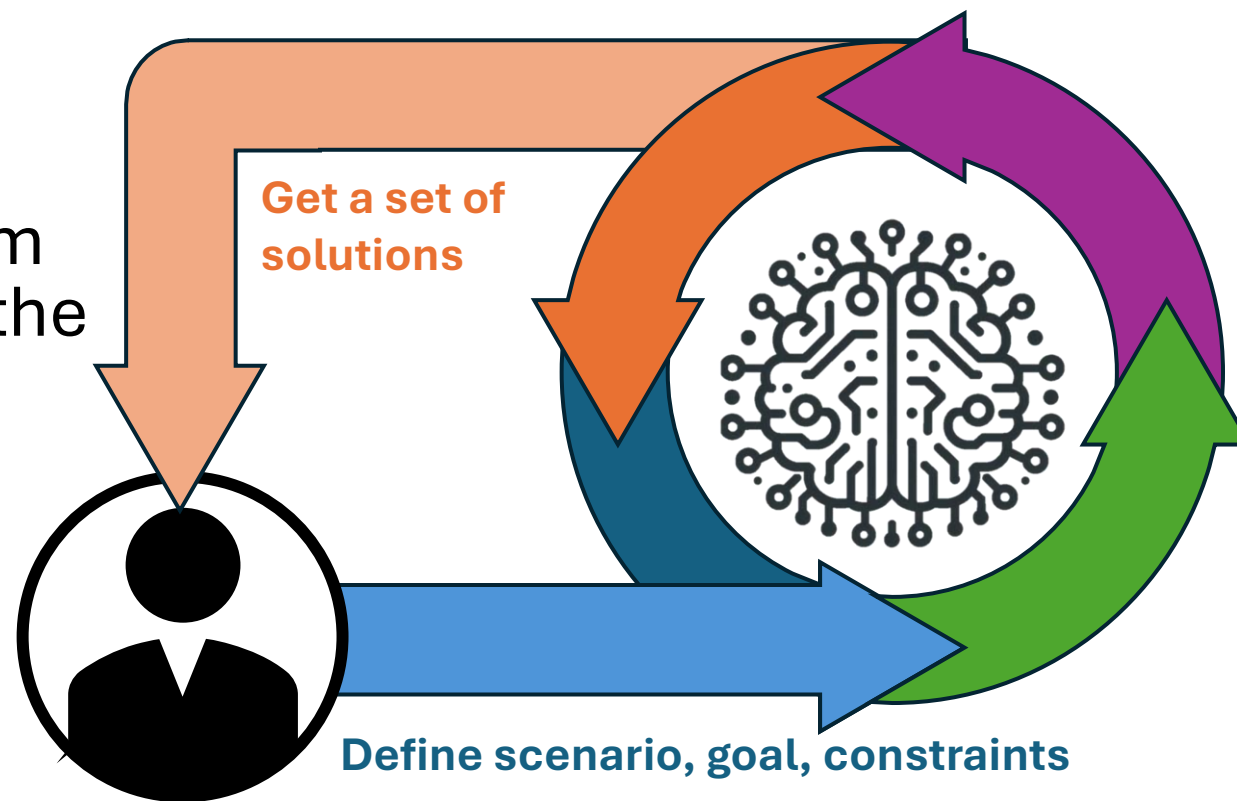
Scenario Editor

- A **scenario editor interface** has been developed and integrated in the Snap4City platform

- The editor let the user
  - Select an area of interest
  - Load the required data from the digital twin in operation
  - Introduce changes
  - Invoke analytics or optimization processes
  - Inspect the results
  - Save/load/edit defined scenarios
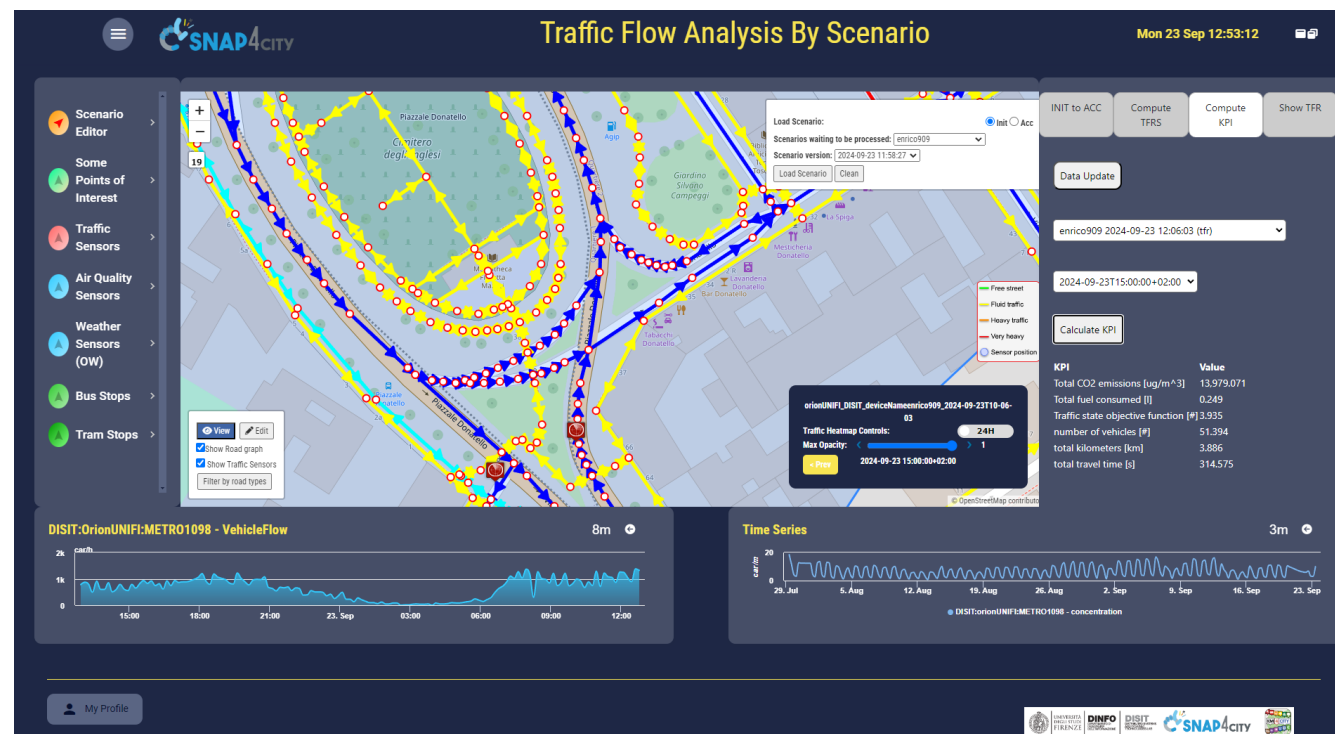
Big Data Challenges

Data explosion

- Each scenario is a **copy of the digital twin** in operation
- Scenarios and results produced by the analytics must be **collected** and **indexed**
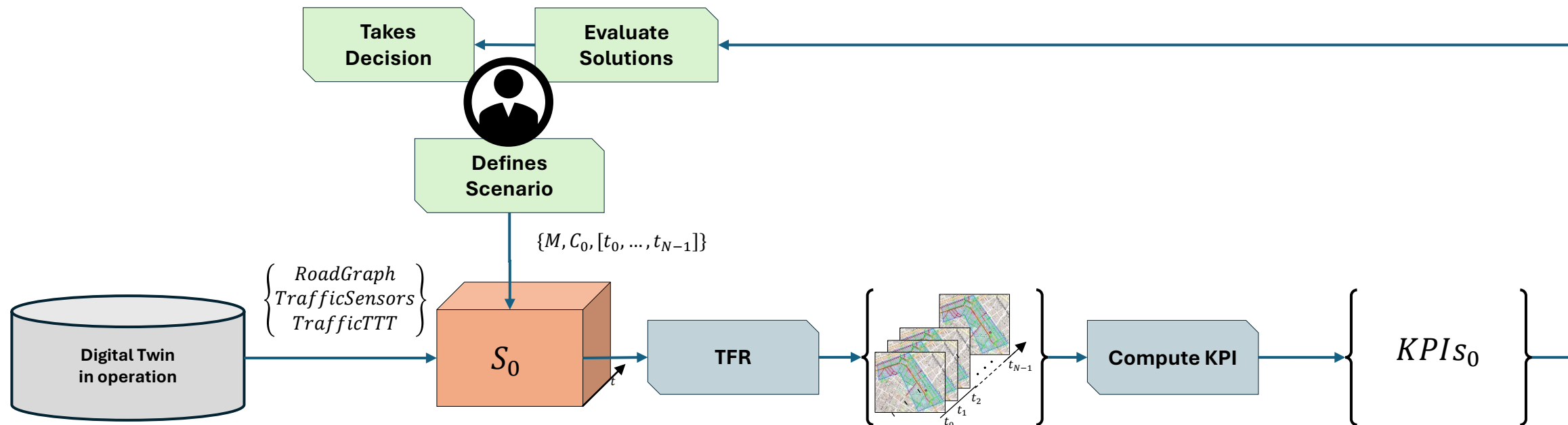
Computational cost

- The execution of the analytics for what-if analysis or optimization requires adequate **computational resources** (CPUs, GPUs, RAM, etc.)
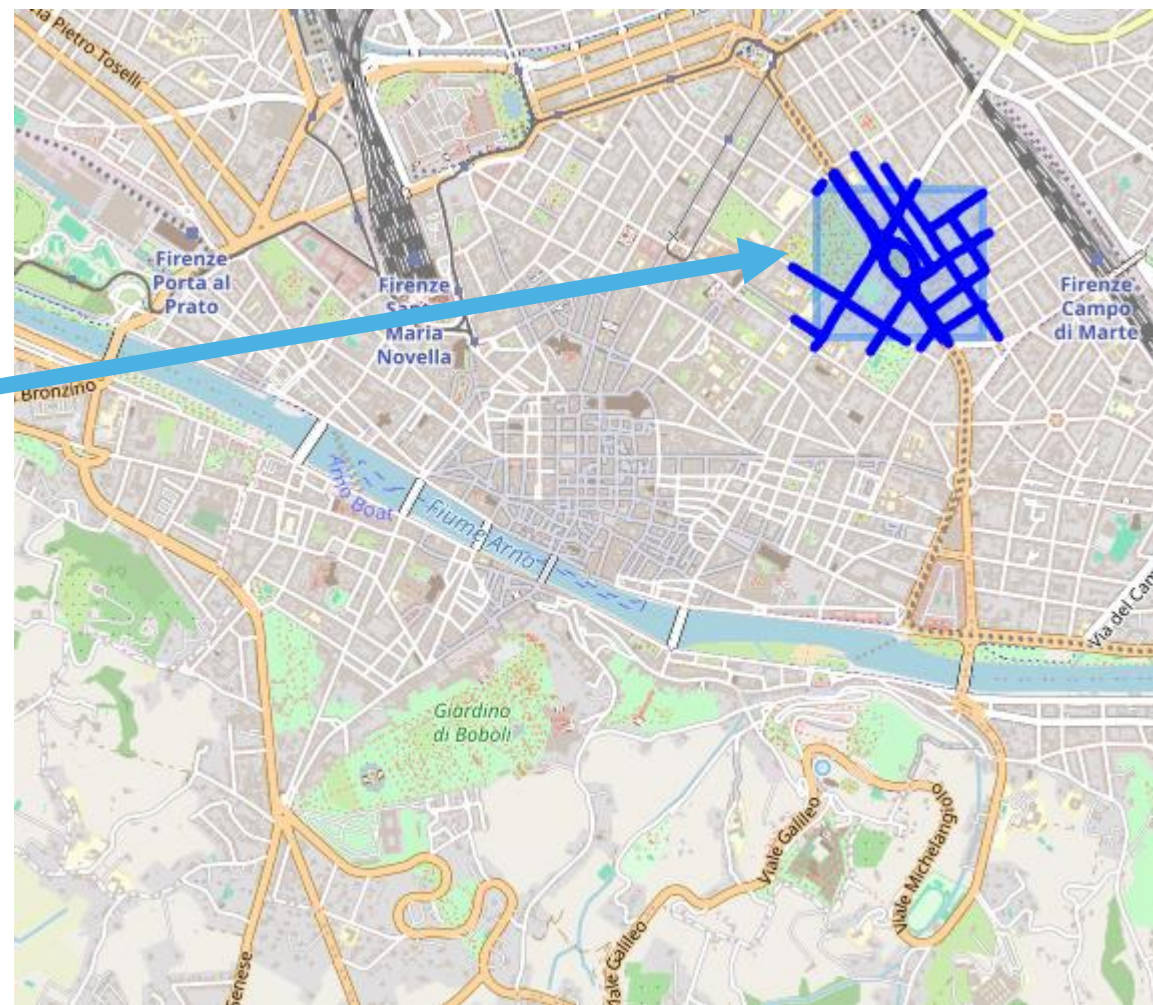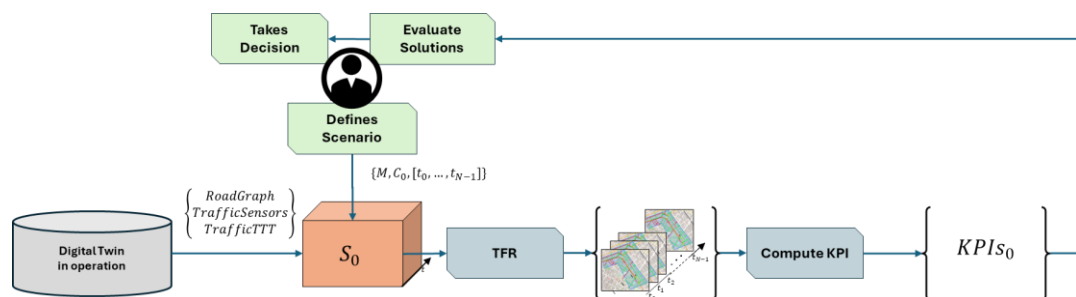
Collaborative working

- Multiple users can **operate simultaneously** on the platform or perform multiple analysis in parallel

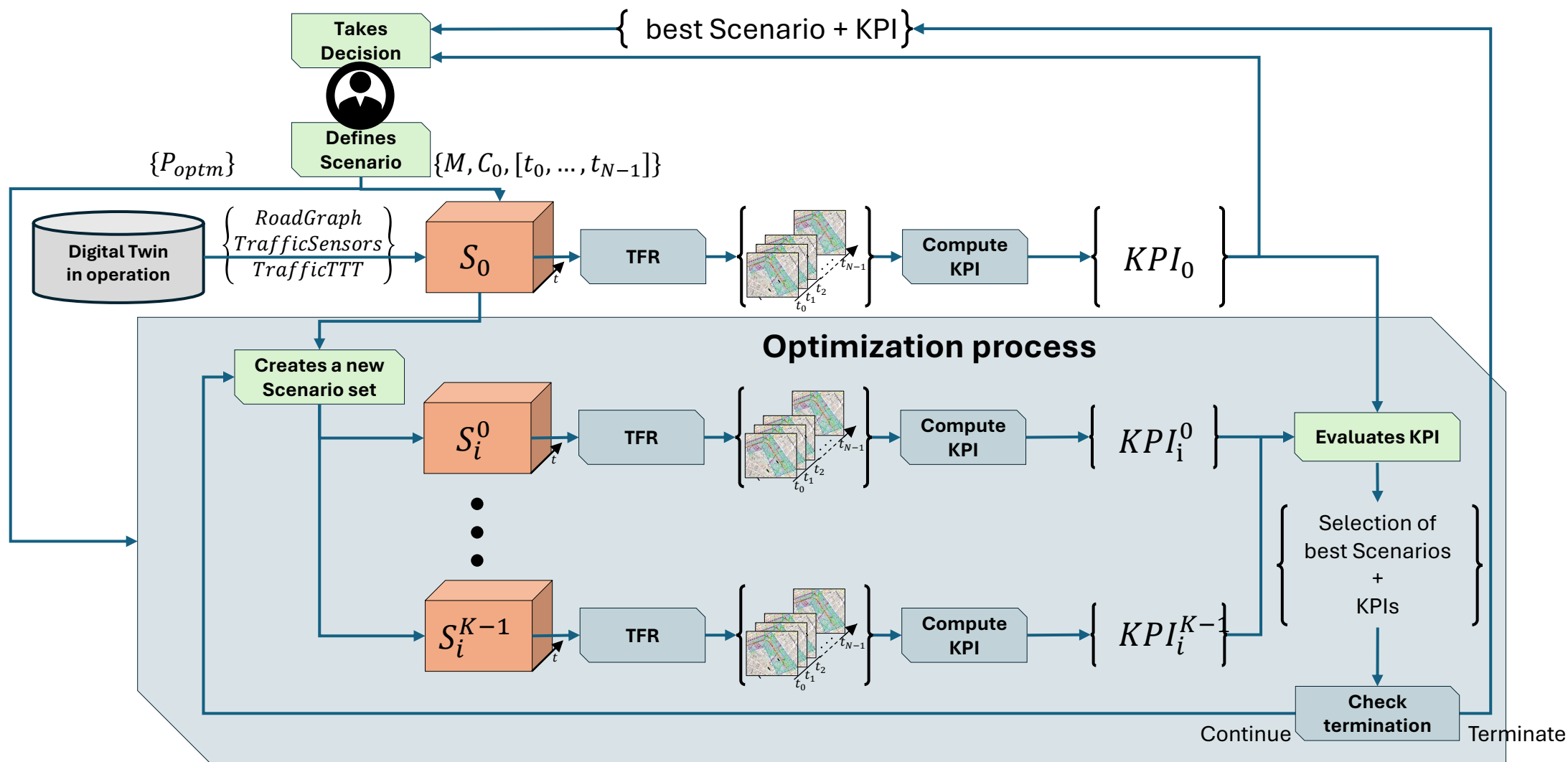# Example: Traffic Flow Analysis What-if

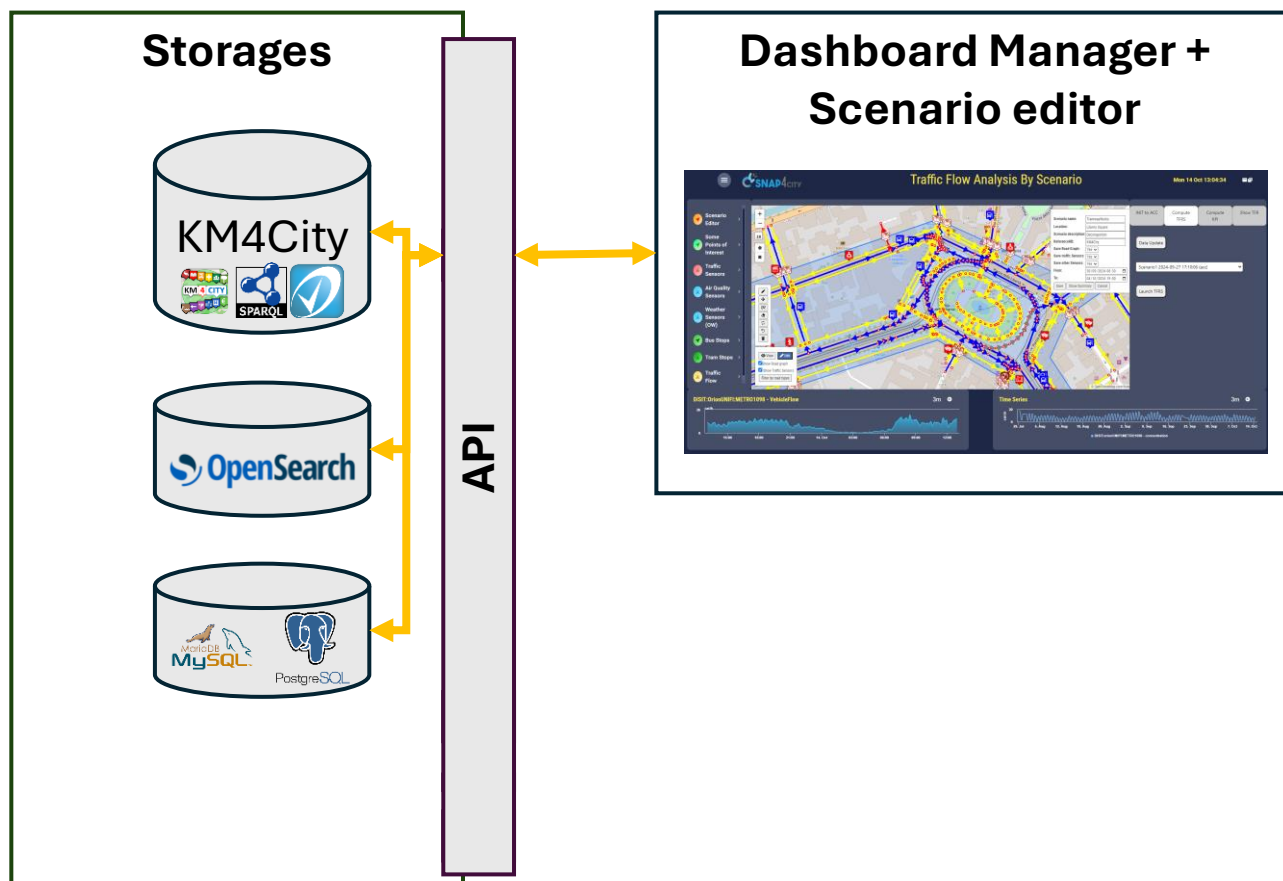# Example: Traffic Flow Analysis What-if

- In the considered area (very small portion of Florence, Italy) more than 300 road segments are included

- A traffic analysis for 24 hours on 7 days would produce more than 50,000 densities
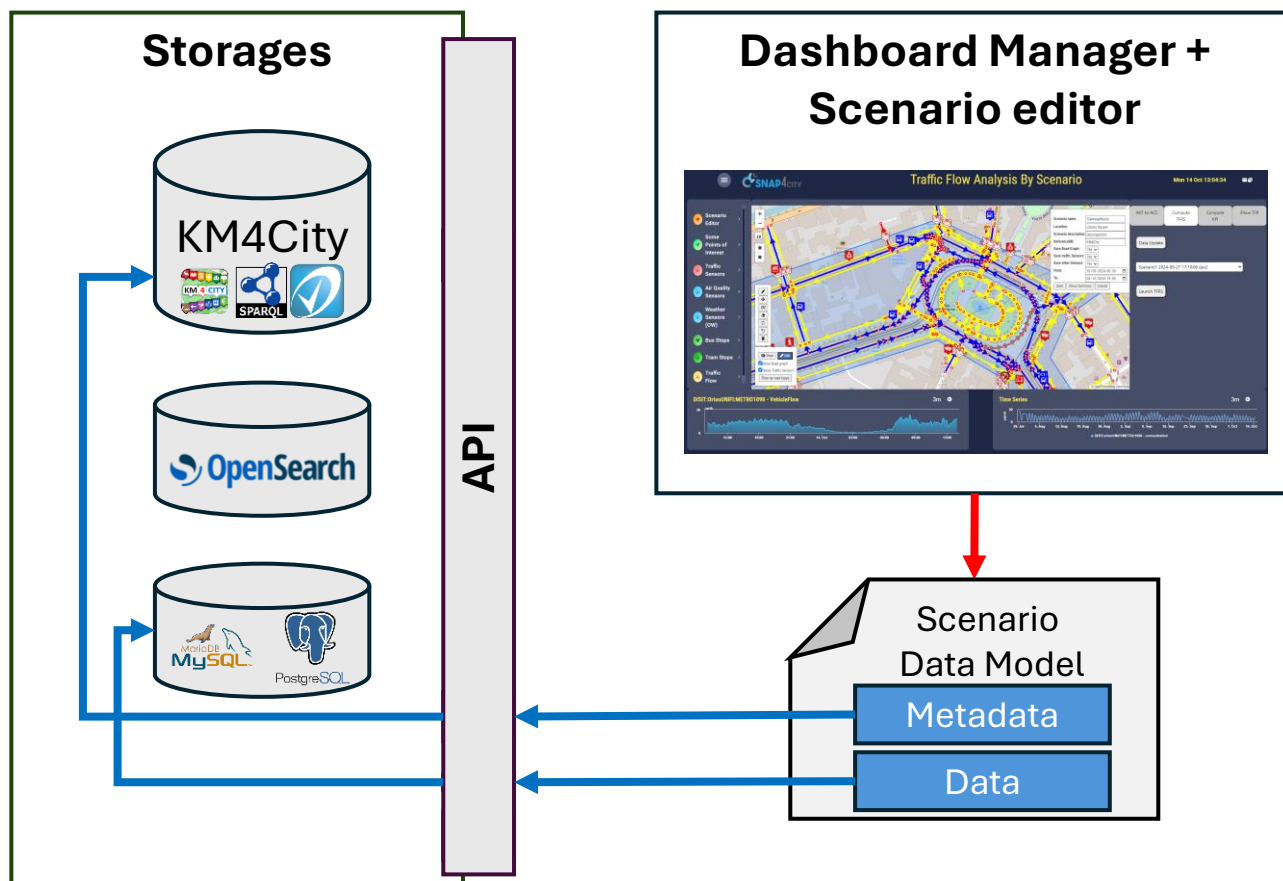
Example: Traffic Flow Analysis Optimization
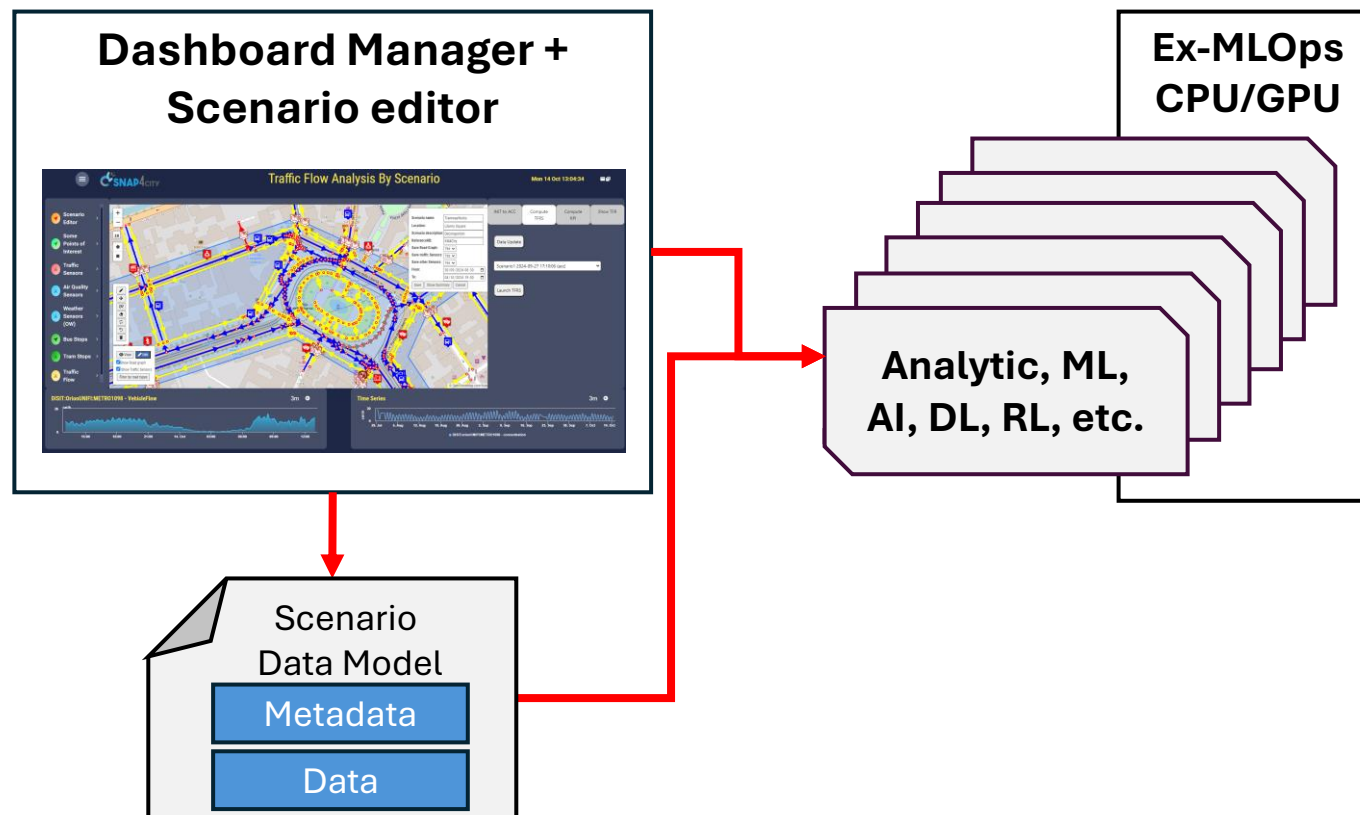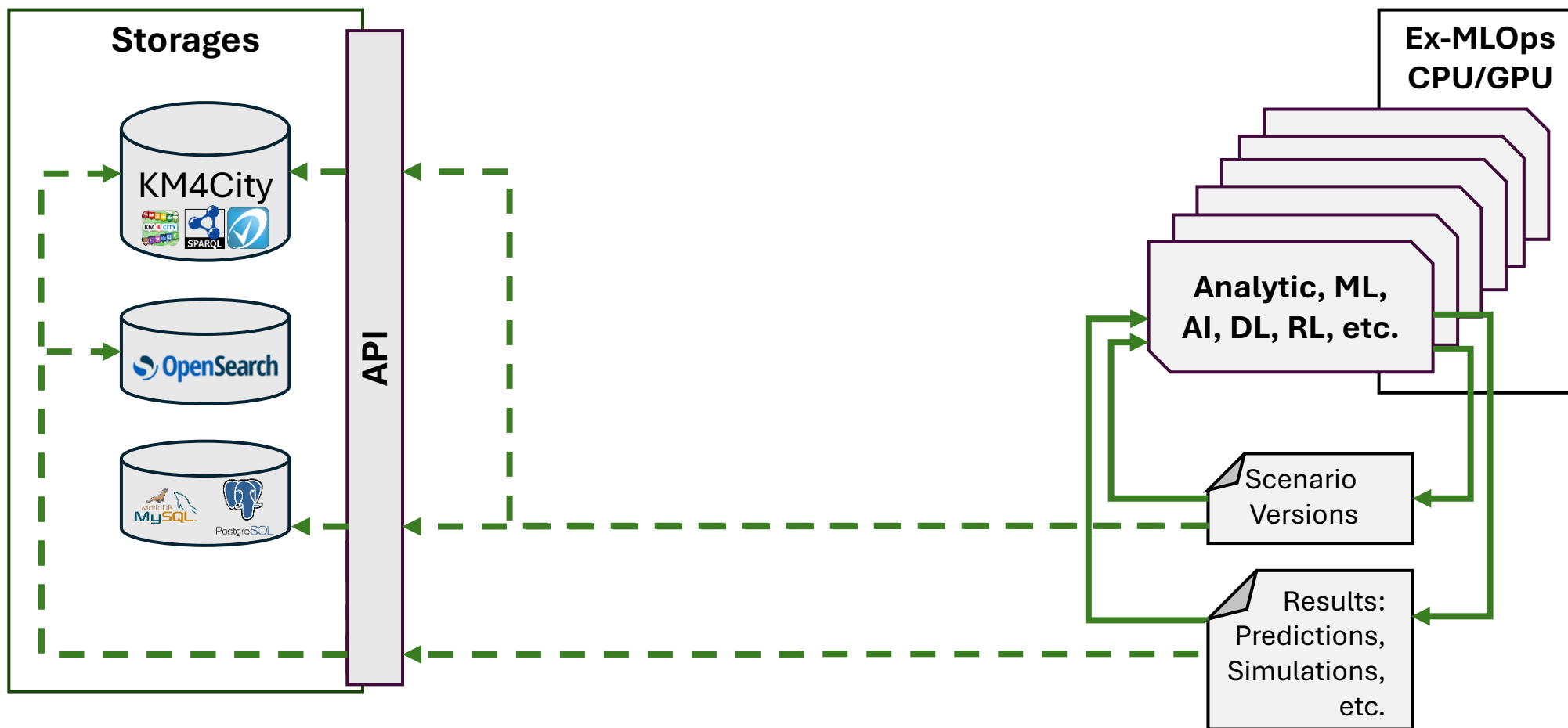
Proposed solution

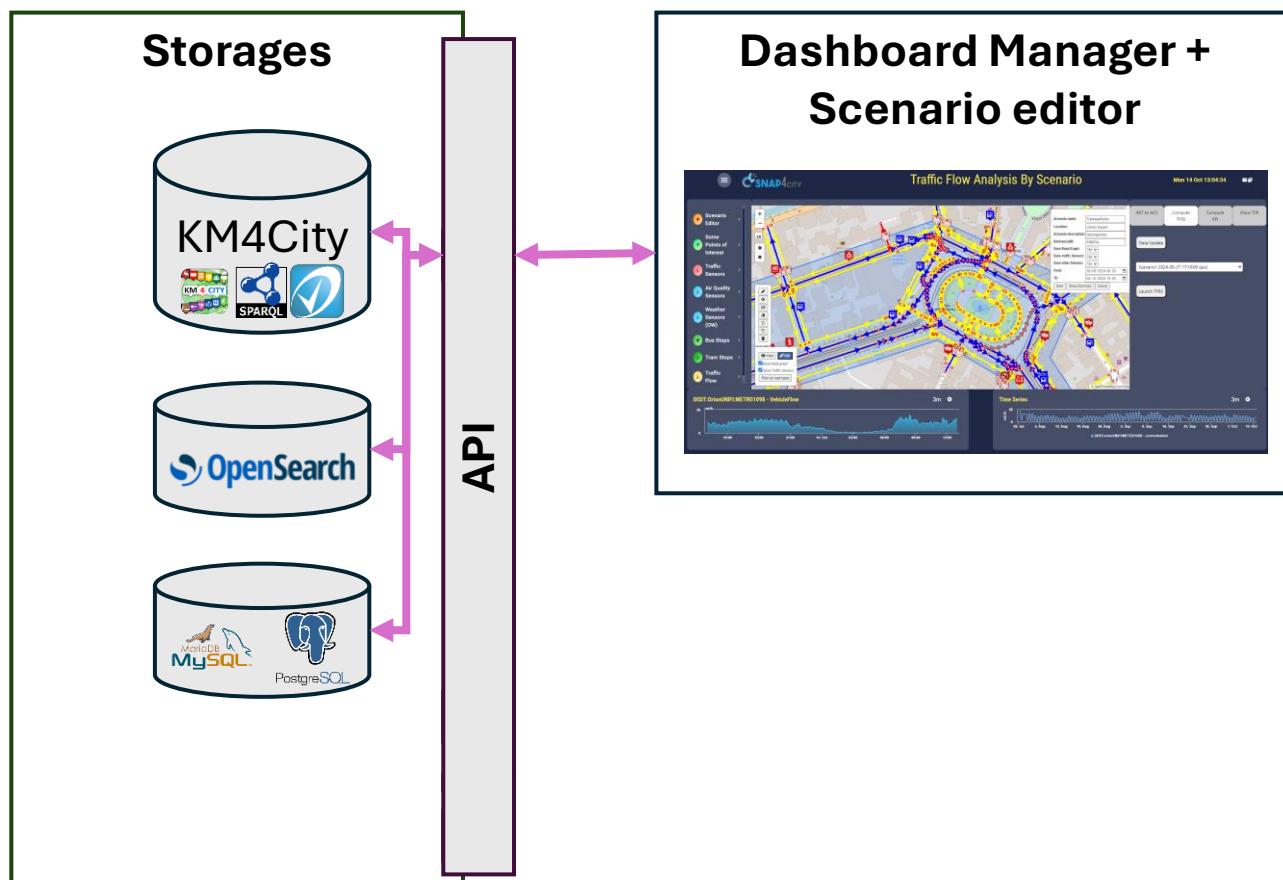# Proposed solution

Proposed solution
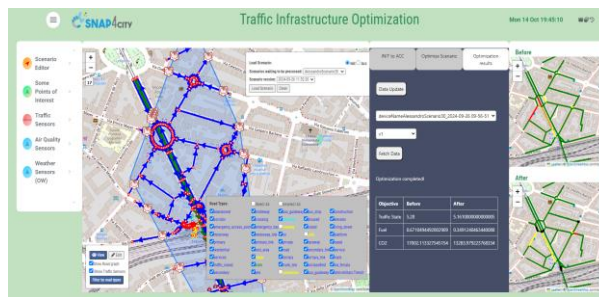
Optimization

Proposed solution

Proposed solution

Examples in operation

- The proposed architecture **has been implemented** in the Snap4City platform and currently used for
  - Traffic analysis
  - Traffic infrastructure optimization
  - Optimization of traffic light plans
  - Computation of heatmaps and predictions

Italian Center for Sustainable Mobility - MOST

- This research activity has been carried out in the context of the **Italian Center for Sustainable Mobility (CN MOST)** and its sub-projects **SASUAM** and **OPTIFaaS**

- The activities aim at producing **novel analytics** for mobility planning and a **microservice infrastructure** for data and software usage and distribution

- The projects exploit the **Snap4City** platform integrated with a High Performance Computing infrastructure

Conclusion

- A **Smart City Digital Twin architecture** has been proposed to support urban mobility planning thought scenario-based **what-if analysis** and **optimization**

- The architecture exploits **data models**, **multiple storages**, and is based on **microservices**

- The solution is able to **scale on big data** and **integrate and manage complex analytics** to offer tools for monitoring, what-if analysis, and automatic generation on suggestion based on optimization

- The solution has been implemented into the Snap4City platform and **offers decision-makers valuable insights going beyond traditional modelling**

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Thank you for your attention!

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