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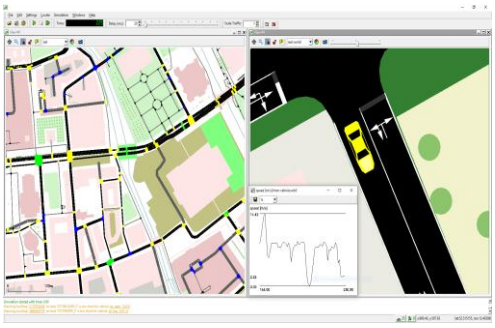

SMART CITY CHALLENGE 2024
Solution idea for the city challenges

Solution Idea Title - Safe Mobility Intelligence Platform

Planned pilot project duration – 24 months

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1. Which urban challenge or problem are you planning to provide a solution to?

Traffic Data Insights for Safe City.
https://finestcentre.eu/challenge-proposal/traffic-data-insights-for-safe-city/

2. The solution you are proposing

The Safe Mobility Intelligence Platform (SMIP) is an integrated analytics and simulation environment that transforms traffic counts, multimodal mobility flows, and public transport ticket validations into actionable insights for safer and more efficient city mobility systems. Its core pillars are an advanced analytics layer built on Apache Superset, a simulation engine powered by Eclipse SUMO, and an optional AI extension that elevates the platform beyond classical analytics.

- https://superset.apache.org/
- https://eclipse.dev/sumo/

Supporting these layers is an event-driven data pipeline using Apache Kafka, enabling seamless ingestion, harmonization, and scenario generation. Superset provides a fully no-code analytics environment, meaning municipal staff can explore mobility patterns, safety hotspots, and transit demand without any programming or data-science skills.

2.1. Analytics & Decision Layer – Apache Superset at the Core

Apache Superset acts as the decision-maker's cockpit, offering an intuitive, no-code environment for mobility analysts, planners, and political stakeholders. The platform provides:

a. Multimodal Mobility Dashboards

Superset visualizes cycling flows, pedestrian volumes, car traffic, and public transport ticket validations through heatmaps, direction-based flows, occupancy graphs, and temporal patterns. These dashboards enable planners to identify peak stress points, underserved routes, and seasonal or event-driven anomalies in a fraction of the time required today.

b. Safety & Conflict Risk Index

An AI-enhanced Spatio-Temporal Safety Model (based on graph neural networks and temporal encoders) produces a real-time Risk Index per road segment or intersection.

Superset dashboards expose: (i) Probabilistic hotspots, even where accident data is sparse, (ii) Multi-modal conflict potential (e.g., car–cyclist or pedestrian–vehicle interactions), (iii) Weather and event sensitivities, (iv) Time-of-day and school-hour risk spikes

This provides a scientifically defensible basis for prioritizing low-cost safety interventions or planning larger infrastructure projects.

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c. Public Transport Demand & Optimization Analytics

Forecasting models predict boarding, alighting, and occupancy per stop and hour, enabling planners to explore: (i) Demand-driven frequency adjustments, (ii) Route extensions or short-turn loops, (iii) Optimal positioning of interchange nodes.

Superset visualizes scenarios side-by-side, supporting transparent and evidence-based decision-making.

2.2. Simulation & Policy Testing – Eclipse SUMO Integration

The simulation core uses Eclipse SUMO as a digital twin for mobility networks. SMIP exports real-world traffic patterns and AI-generated forecasts into SUMO network and route files, enabling cities to test policies and infrastructure safely before implementation.

Using SUMO, SMIP evaluates: (i) New cycle lane configurations, (ii) Intersection redesigns or signal retiming, (iii) Pedestrianization measures, (iv) Bus route restructuring, frequency changes, and integration with micro-mobility.

SUMO simulations generate quantitative KPIs: queue lengths, intersection delays, multi-modal conflict points, emissions, bus punctuality, and walking/cycling accessibility changes. The results are automatically visualized in Superset dashboards for before/after comparison, enabling decision-makers to quantify the impact of proposed interventions.

AI Counterfactual Engine

AI modules generate realistic what-if scenarios, allowing SUMO to test not only engineering concepts but also operational ones—dynamic timetabling, event-day traffic management, adaptive cycling corridors, and resilience planning. This elevates SUMO from a simulation tool to an intelligent policy laboratory.

2.3. Supporting Layer – Event-Driven Data Pipeline with Apache Kafka

The entire system is supported by an event-driven architecture built on Apache Kafka. Kafka topics ingest and structure data from traffic counters, public transport systems, IoT devices, vehicle telemetry, and contextual information. Stream processors provide real-time cleaning, feature extraction, and storage into analytical databases used by Superset and into scenario repositories consumed by SUMO.

Kafka ensures: (i) Scalable real-time ingestion, (ii) Modular integration of new sensors, (iii) Continuous availability of fresh data for dashboards and simulations

Though not the centerpiece, this layer is essential for enabling the continuous, AI-assisted intelligence loop that SMIP provides.

2.4. Outcome

SMIP delivers a future-proof, scientifically robust platform that unifies analytics, simulation, and AI. Cities gain real-time visibility, reliable safety risk predictions, and the ability to test mobility policies virtually—resulting in safer streets, optimized public transport, and smarter infrastructure investments. It helps city staff make decisions more easily with clear, data-based insights. SMIP saves time and money by allowing the city to test ideas digitally before building anything. It also supports cleaner air and better energy use by improving traffic flow and public transport.

2.5. Specific Feedback-Based Features

- As according to the needs of the city Dún Laoghaire, Ireland, the architecture of the solution will be designed as adaptive, allowing for the smart integration of various data services and existing city's solutions.

3. Innovation and piloting of your pilot solution

Current solutions include CityFlow and A/B Street for traffic simulation, and cloud analytics stacks like Snowflake/BigQuery, Databricks, Fivetran/Airbyte, and PowerBI for data processing and visualization. These tools are powerful but operate in isolation: simulators lack integrated real-world data pipelines, while analytics platforms rarely provide mobility-focused scenario testing. SMIP is better by combining Superset analytics, SUMO simulation, and event-driven data ingestion into one unified mobility intelligence loop. Its key innovation is the AI counterfactual engine, which automatically generates and evaluates "what-if" mobility and safety scenarios—something no current off-the-shelf solution delivers end-to-end. The main value is that all data, analysis, simulation, and planning tools work together in one unified system.

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What do the cities need for piloting the proposed solution? How the piloting could work?

All components needed for the solution are open source. No additinional are required. SUMO is best of breed in its domain. Given the experience of TalTech and its partners we will achieve a Technology Readiness Level TRM 7 (System prototype demonstration in operational environment) for the pilot.

Capabilities of the research and development proposed team.

We have two decades of experience in designing and implementing large-scale data driven systems, always leading-edge and innovative. Wrt the topic of traffic management:

From the team of Dirk Draheim:

https://ieeexplore.ieee.org/abstract/document/9628206
https://www.sciencedirect.com/science/article/pii/S1877050922004458
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https://www.etis.ee/Portal/Projects/Display/e344ff8c-ce7d-4b03-8db0-ed85cb4a8170

From the team of our partner Arun Kumar Sangaiah:

https://www.sciencedirect.com/science/article/pii/S1084804522001394
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https://ieeexplore.ieee.org/abstract/document/11146479
https://link.springer.com/article/10.1007/S12243-019-00731-9
https://www.sciencedirect.com/science/article/pii/S1389128618300999

4. Expected impact of your pilot solution.

SMIP can significantly improve urban sustainability, safety, and quality of life. By identifying multimodal safety hotspots and optimizing infrastructure investments, it reduces crashes and creates safer walking and cycling environments. Its demand-driven public transport optimization leads to higher ridership, lower car dependency, and reduced emissions. Real-time analytics help cities adjust mobility strategies during events, weather shifts, or seasonal changes. The SUMO-based digital twin supports smarter long-term planning, ensuring interventions are tested before implementation, saving resources and avoiding ineffective projects. Overall, citizens benefit from safer streets, more reliable transit, cleaner air, and mobility systems that adapt proactively to community needs.

By reducing unnecessary vehicle movements and improving bus operations, the platform increases overall energy efficiency across the mobility system. This contributes to cleaner air, lower noise levels, and a more sustainable urban environment.