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Personalized Evacuation Routing System: A Smart Solution for Crisis Management

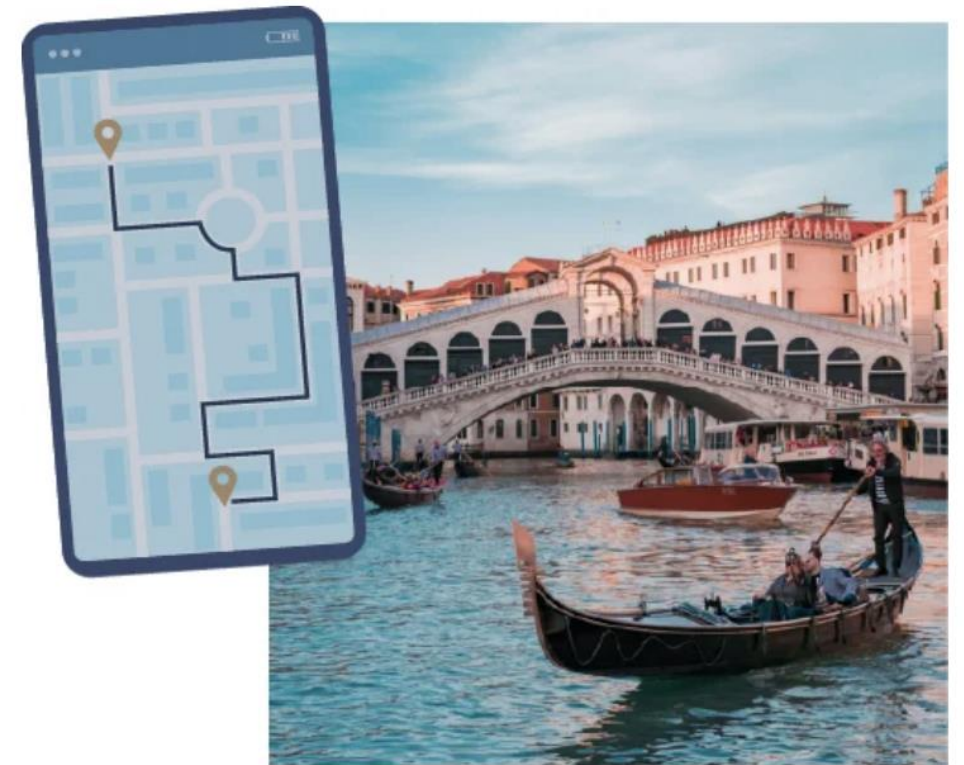
Eduardo Quiñones - BSC

21 Maig 2025

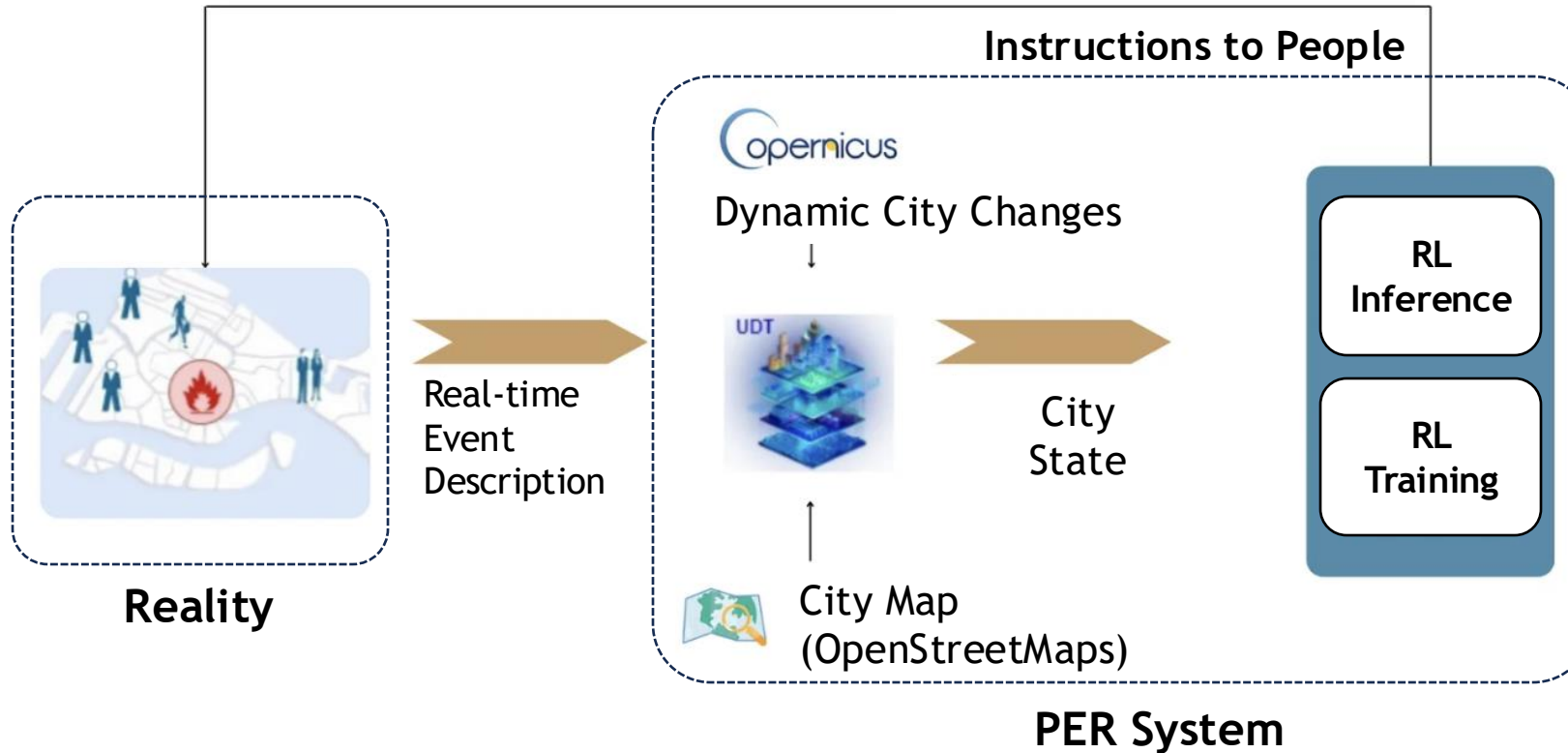
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Personalized Evacuation Routing (PER) System

- Guide citizens in an urban environment (Venice) through a safe route in real time
 - **Motivation:** Crowded touristic city with a very complex city mesh
- Combines two main technologies
 1. **Urban Digital Twin:** An accurate virtual model of the city with real-time data
 2. **Reinforcement Learning:**
 1. **Training phase:** Learns to generate evacuation routes based on simulated city scenarios
 2. **Inference phase:** Generates routes to citizens via mobile app



Personalized Evacuation Routing (PER) System



Two Main Challenges:

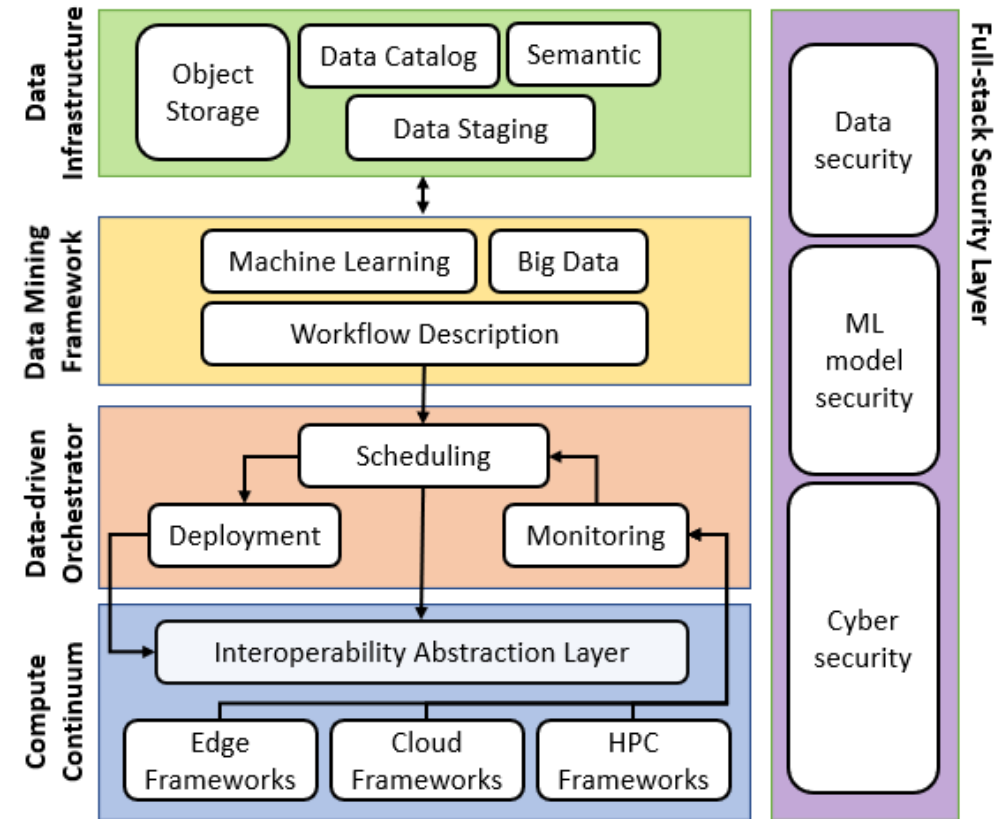
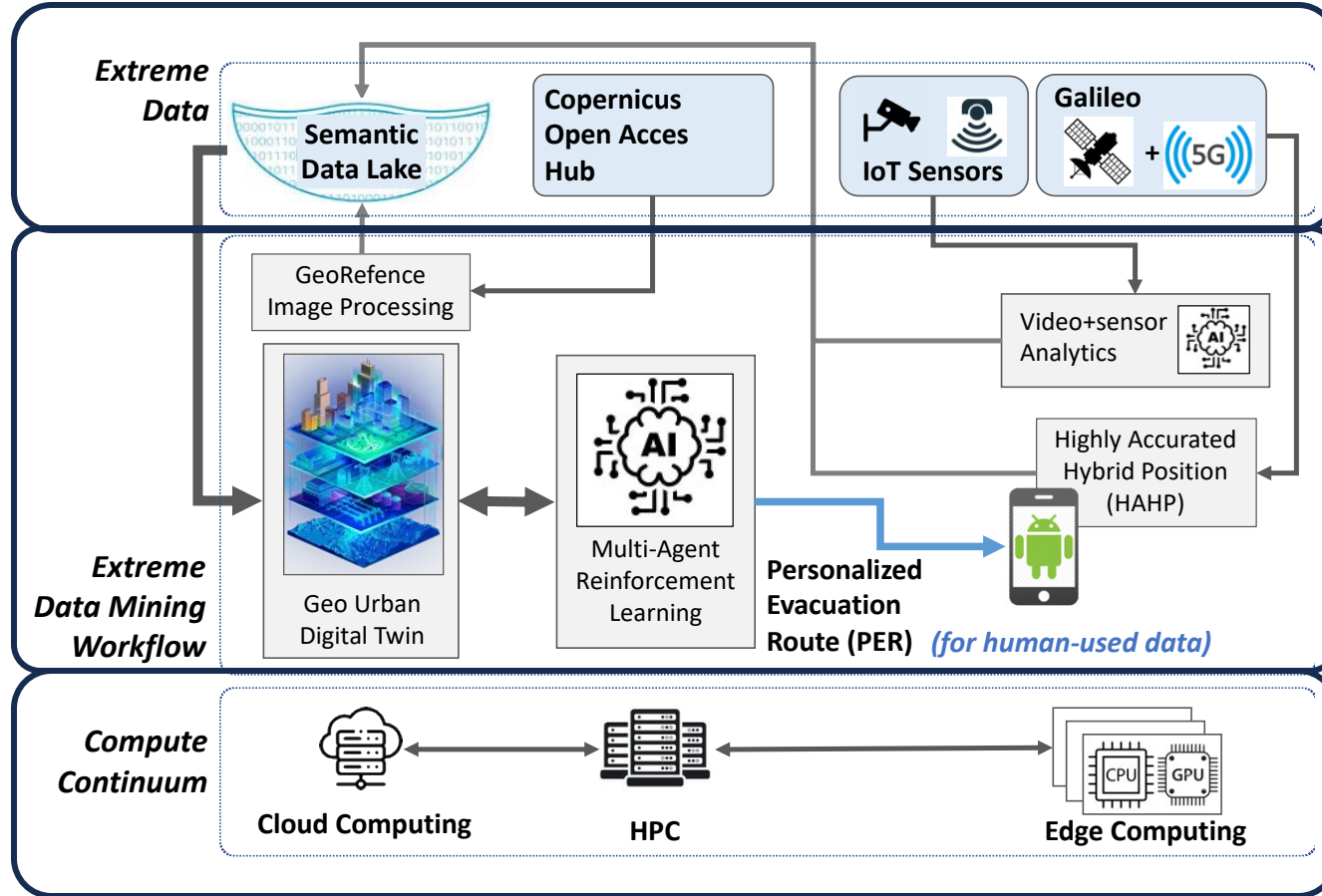
1. System Deployment
2. AI Engine Development

Compute Continuum

1. HPC to support massive parallel processing capabilities and advanced acceleration features
2. Edge Computing to reduce data transmission latencies, minimize data privacy and security risks
3. Cloud Computing to provide highly scalable storage systems and on-demand analytics technologies

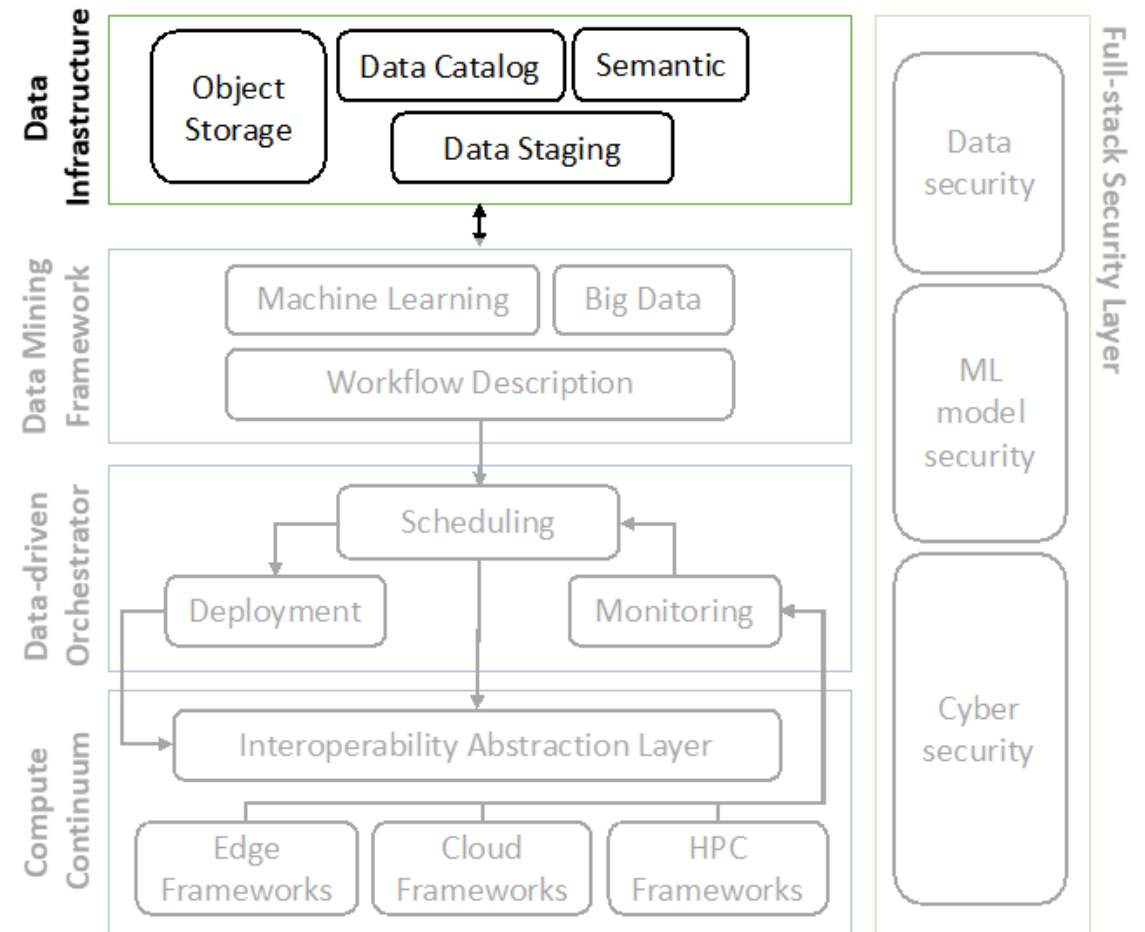
Software Platform

1. Data infrastructures and AI & Big-data frameworks to facilitate the development of complex workflows, including data processes and analytics methods
2. Data-driven orchestration to select the most appropriate computing resources
3. Interoperability of programming paradigms and execution models used across the compute continuum



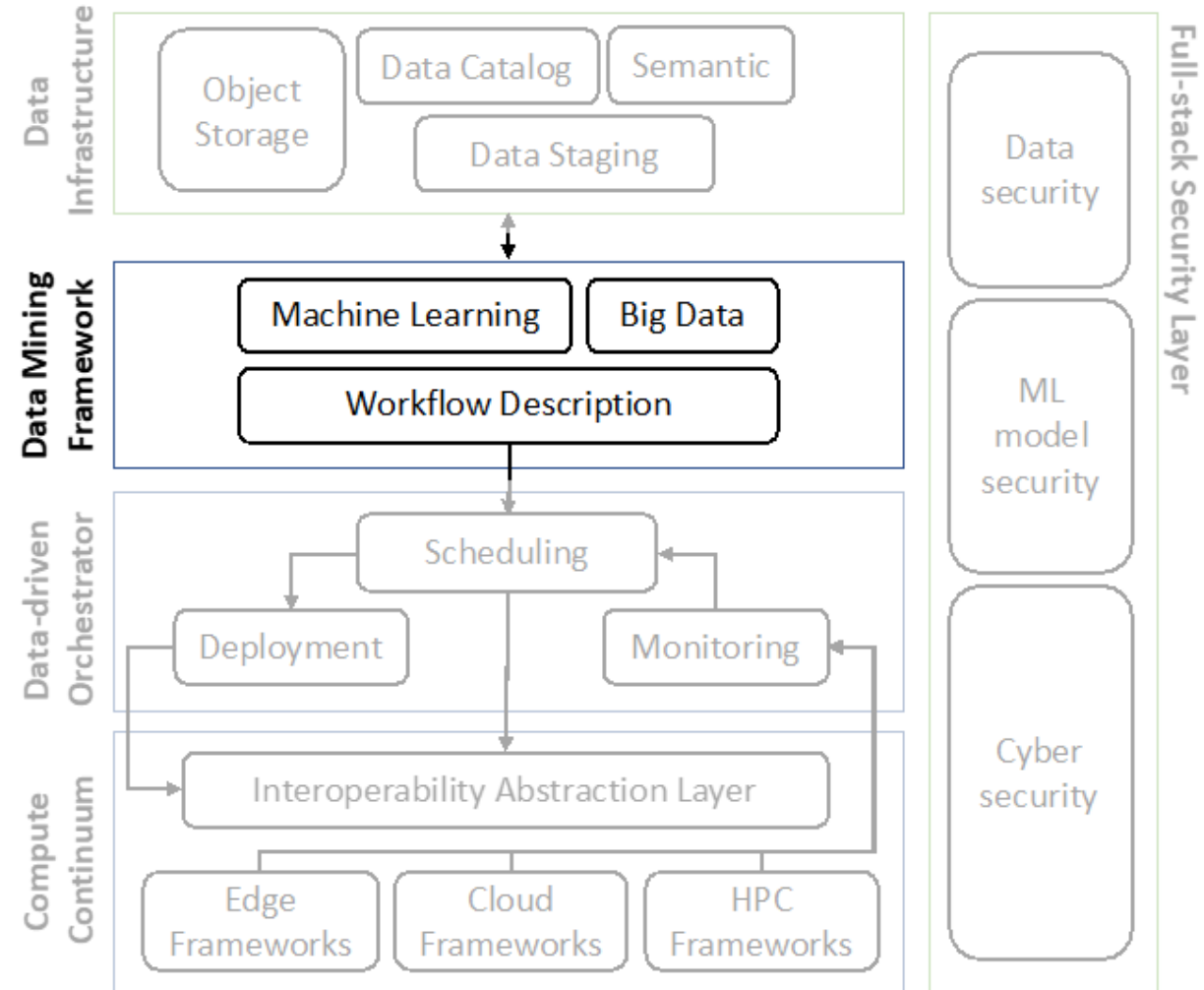
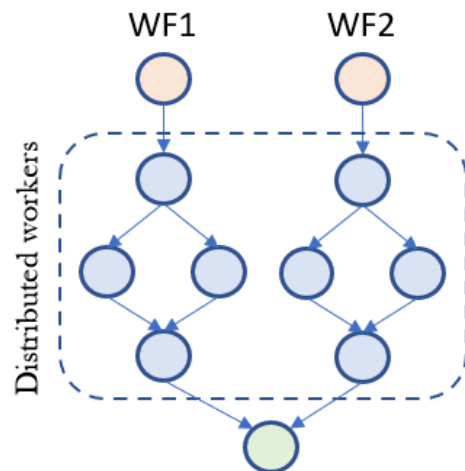
Data Infrastructure

- **Object Storage** as the universal substrate for data management across the compute continuum
- **Data Staging Engine** for containerized data manipulation services
- **Data Catalog** to store metadata information relevant for data preparation, ETL tasks and data query mechanisms
- **Semantic engine** supporting a rich content relationships and models (some of them stored in a graph format)



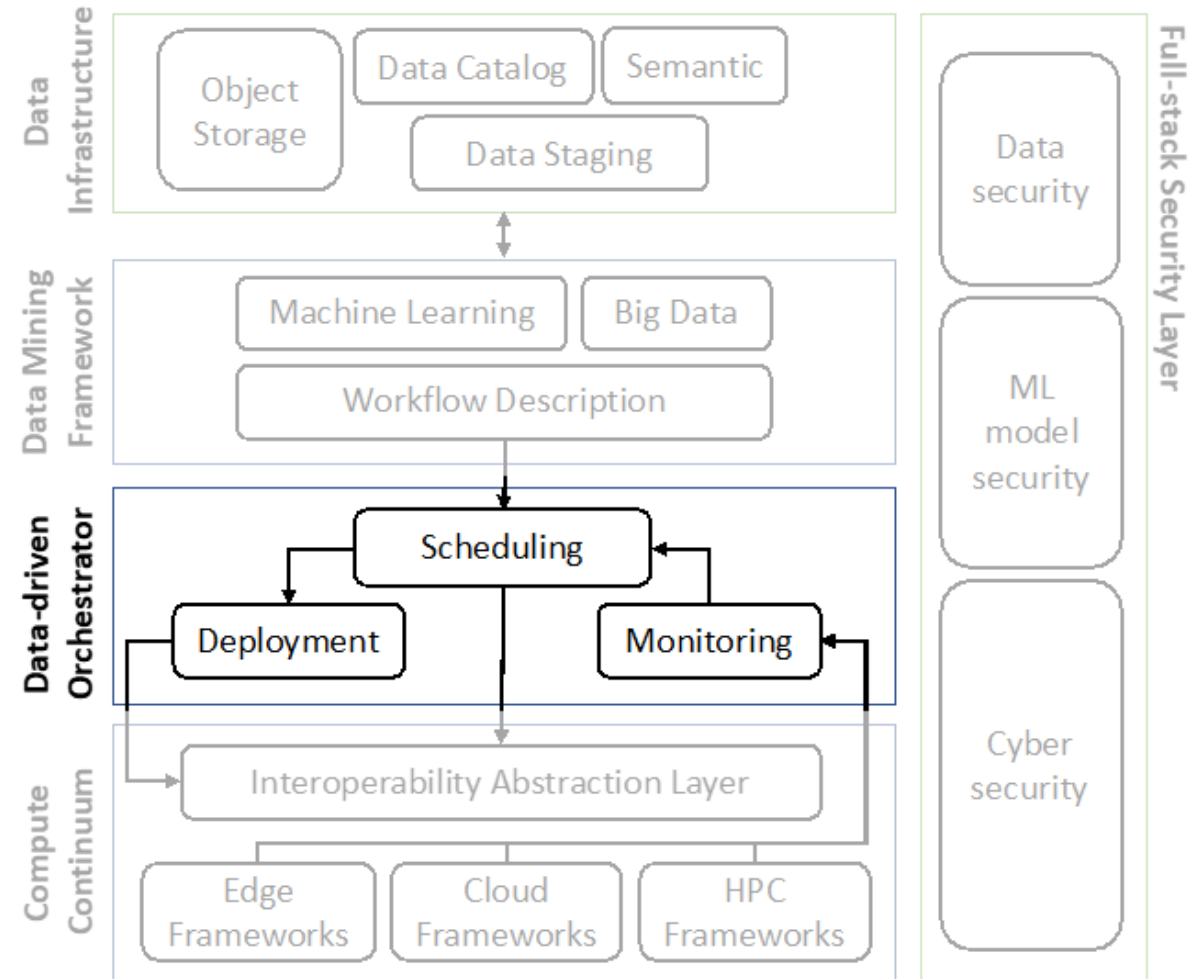
Data-Mining Frameworks

- Enhance software development productivity of complex workflows, unifying data processing and analytics methods
 - **Serverless approach** suited to stateless big data computations
 - **Task- and data-based parallelism** to exploit parallel computation for complex stateful computation
- Interoperability with AI and Big-data frameworks



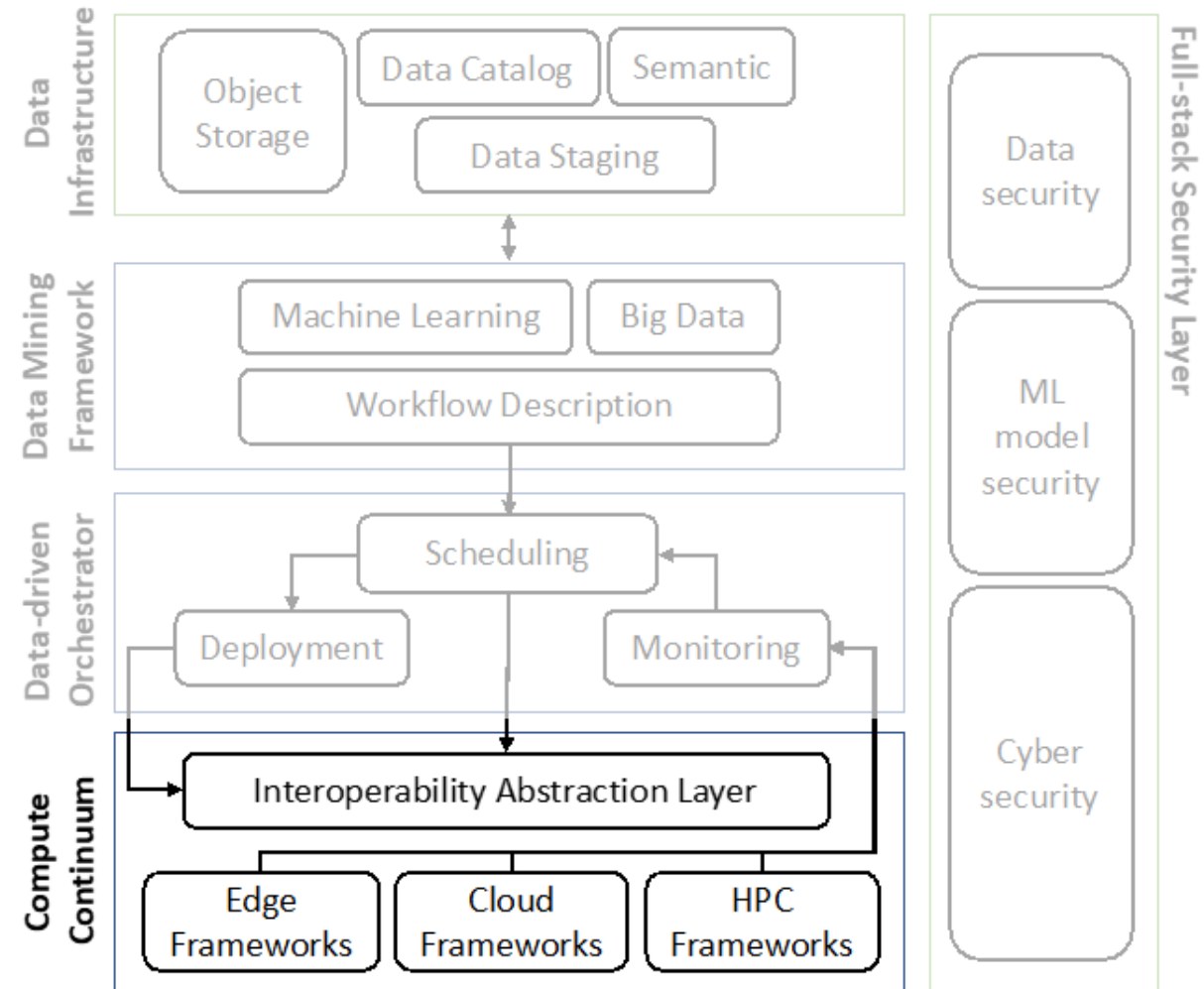
Orchestration and Monitoring

- Select the most appropriate computing resource upon which workflow (data processes and analytics methods) will execute and dynamically adapt the execution to changing execution conditions
 - Based on workflow characteristics and monitoring information across the compute continuum, both at the system and application levels
- Minimize data movements across the compute continuum



Compute Continuum & Interoperability

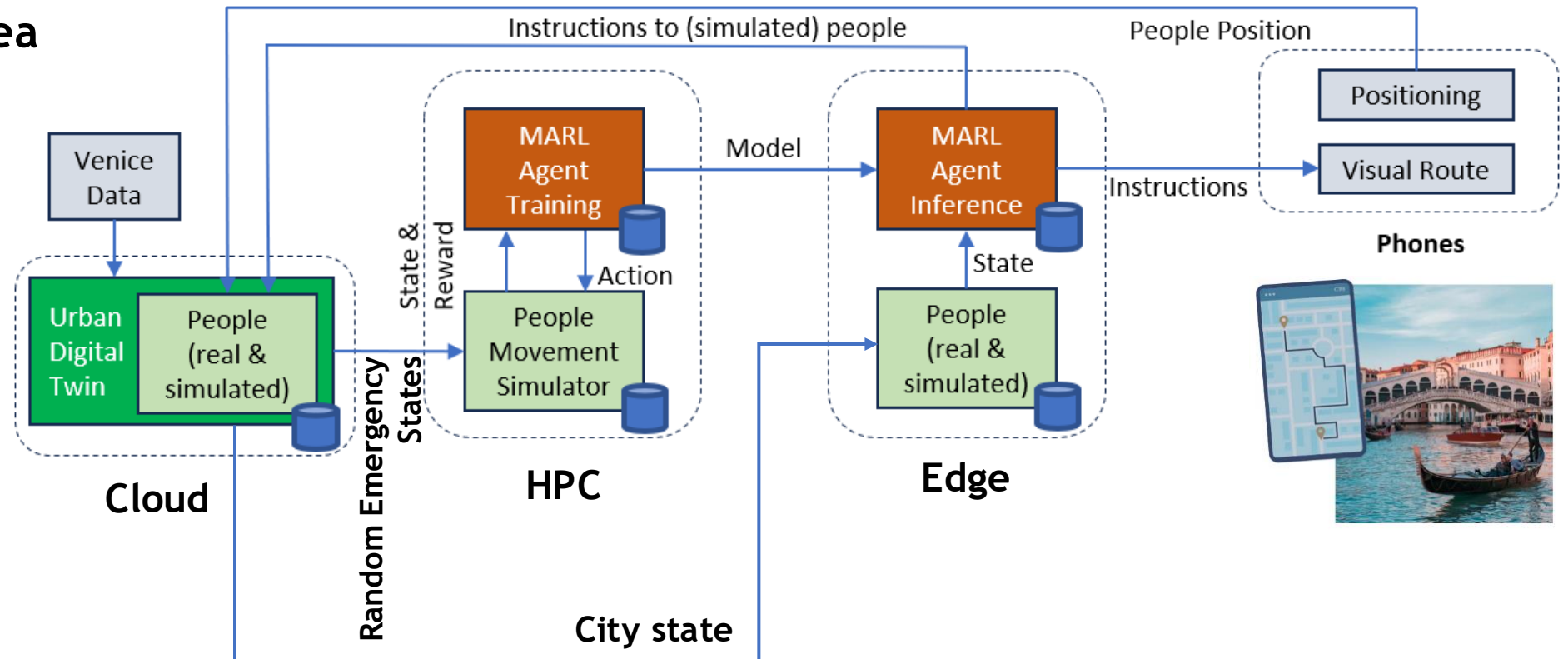
- Unified computing abstraction layer upon multi-cluster Kubernetes solutions
- Use of the most convenient programming paradigms and execution models to exploit the performance capabilities of edge, cloud and HPC resources
- Infrastructure “hidden” to the user, as if everything was executing locally



PER Workflow Description & Deployment

PER Components are deployed and executed in different clusters/node, preserving consistent state and data integrity, while providing a fast real-time response

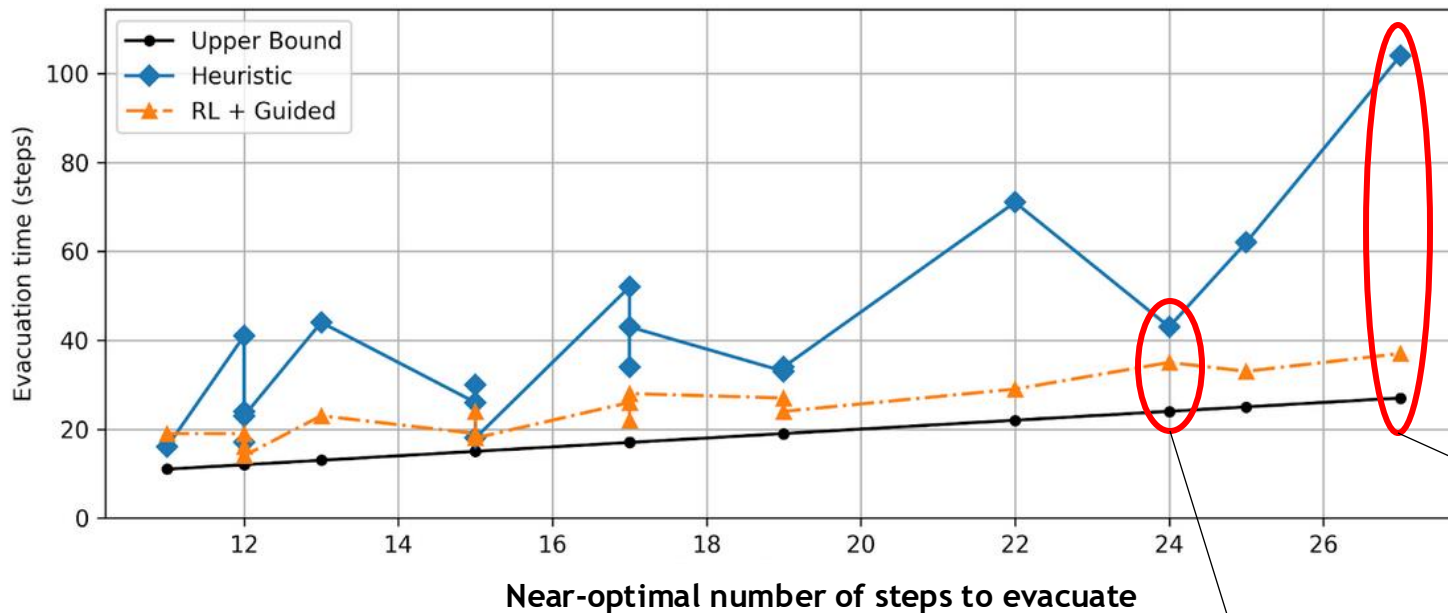
Tronchetto Venice Area



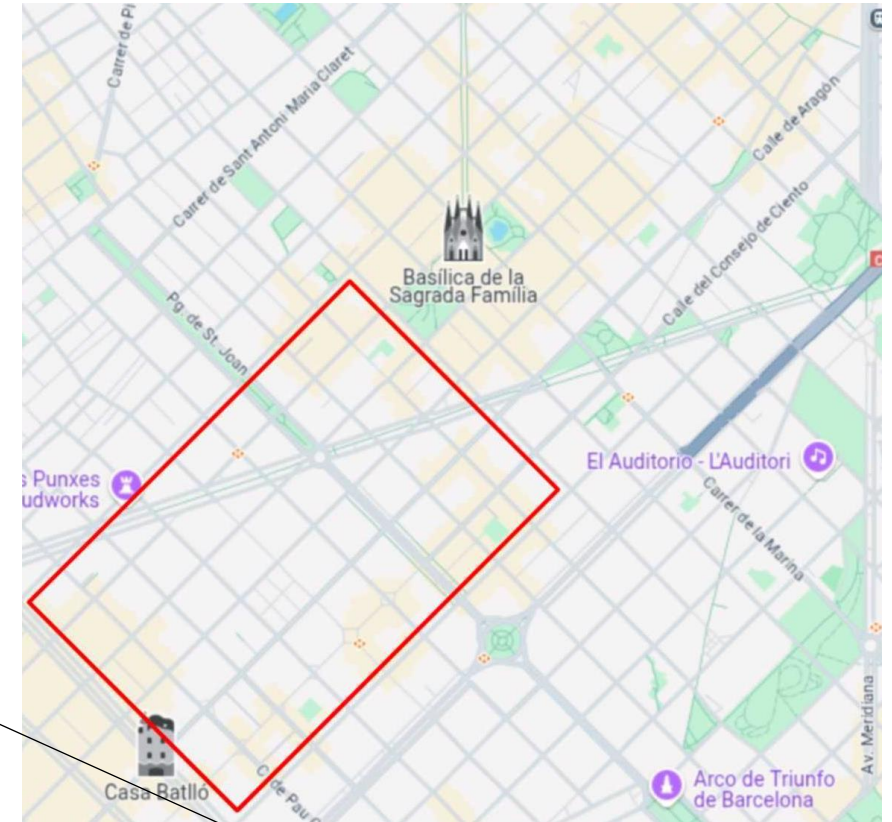
AI Performance of PER on Randomly Generated Maps

An area of BCN with
50 and **80** nodes

18 random maps with 50 nodes and 100 people



Near-optimal: 24 steps
RL + Guided: 35 steps
Heuristic: 43 steps

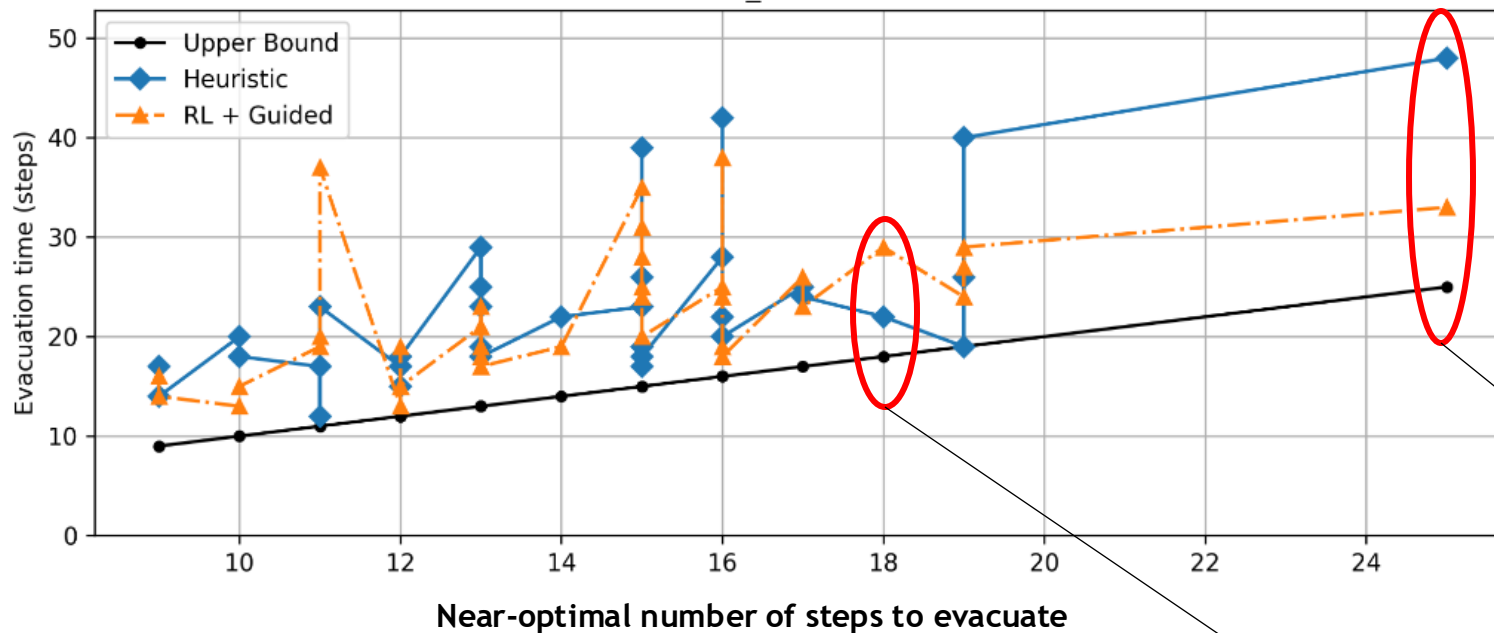


Near-optimal: 27 steps
RL + Guided: 37 steps
Heuristic: 104 steps

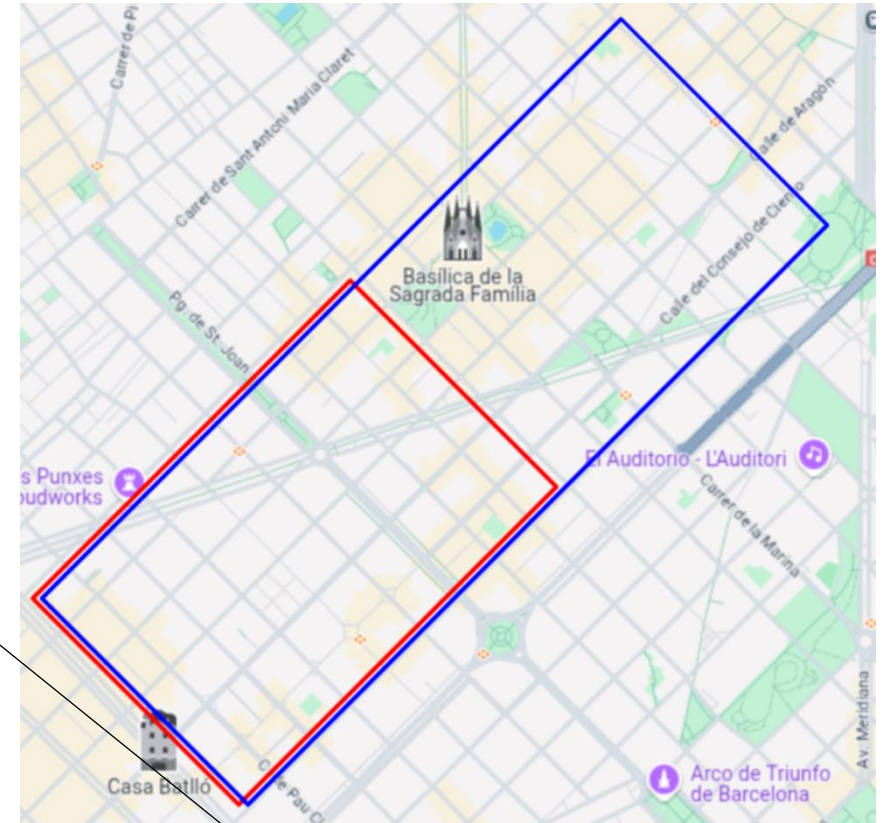
AI Performance of PER on Randomly Generated Maps

An area of BCN with
50 and **80** nodes

36 random maps with 80 nodes and 100 people



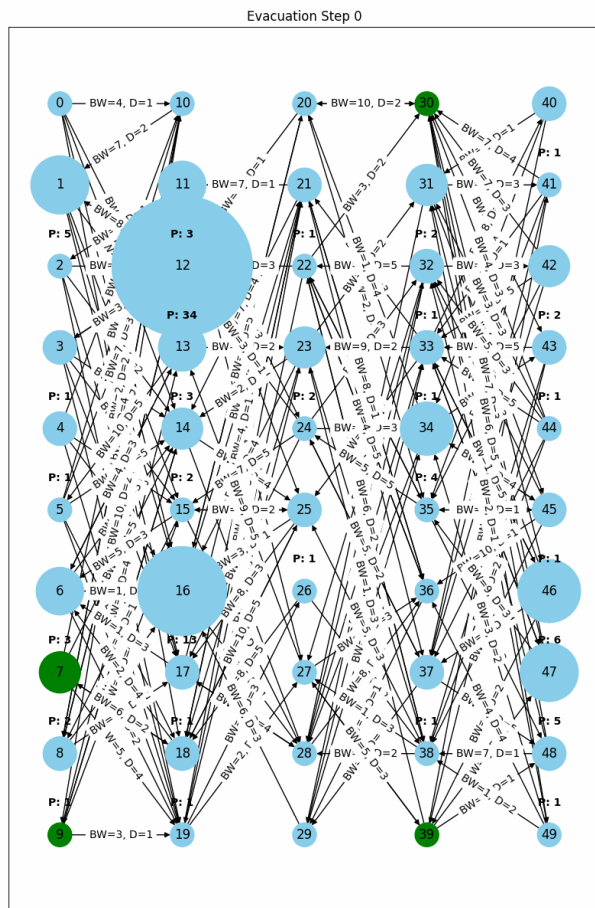
Near-optimal: 18 steps
RL + Guided: 29 steps
Heuristic: 22 steps



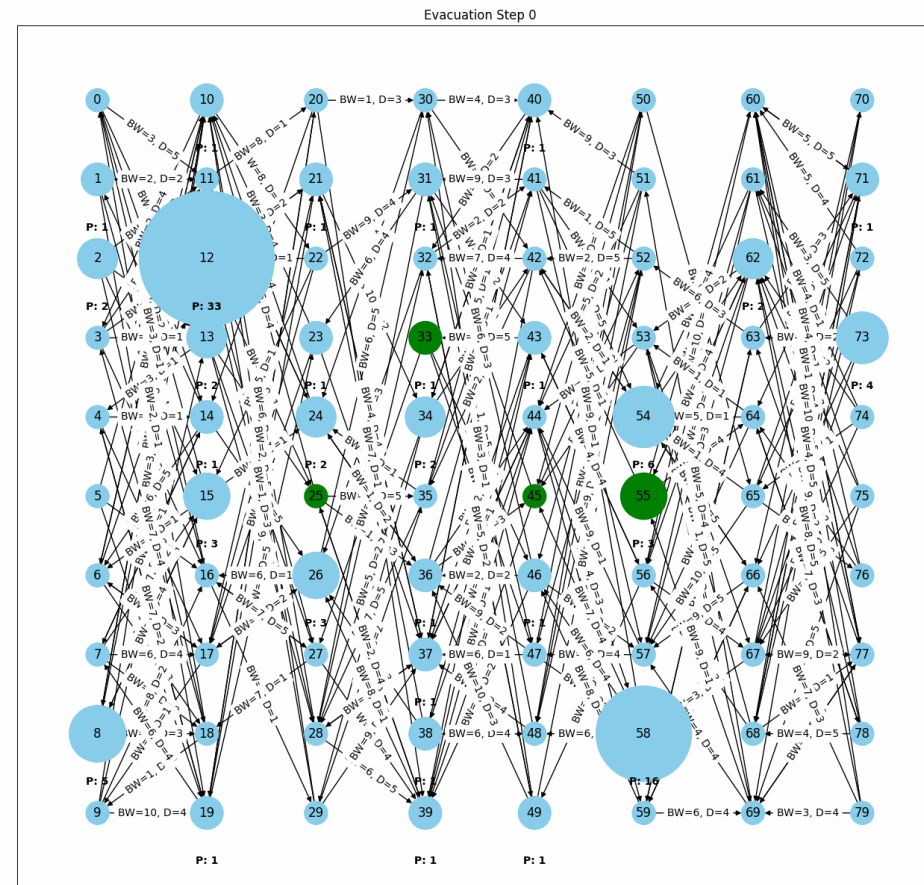
Near-optimal: 25 steps
RL + Guided: 33 steps
Heuristic: 48 steps

Movement of 100 people on Randomly Generated Maps

50 nodes



80 nodes



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