

2026 IEEE 103rd Vehicular Technology Conference
OcéaNice Convention Centre Nice, France
9 – 12 June 2026



A Quantum Method for Constrained Vehicle Dynamics and Green-Wave Optimization

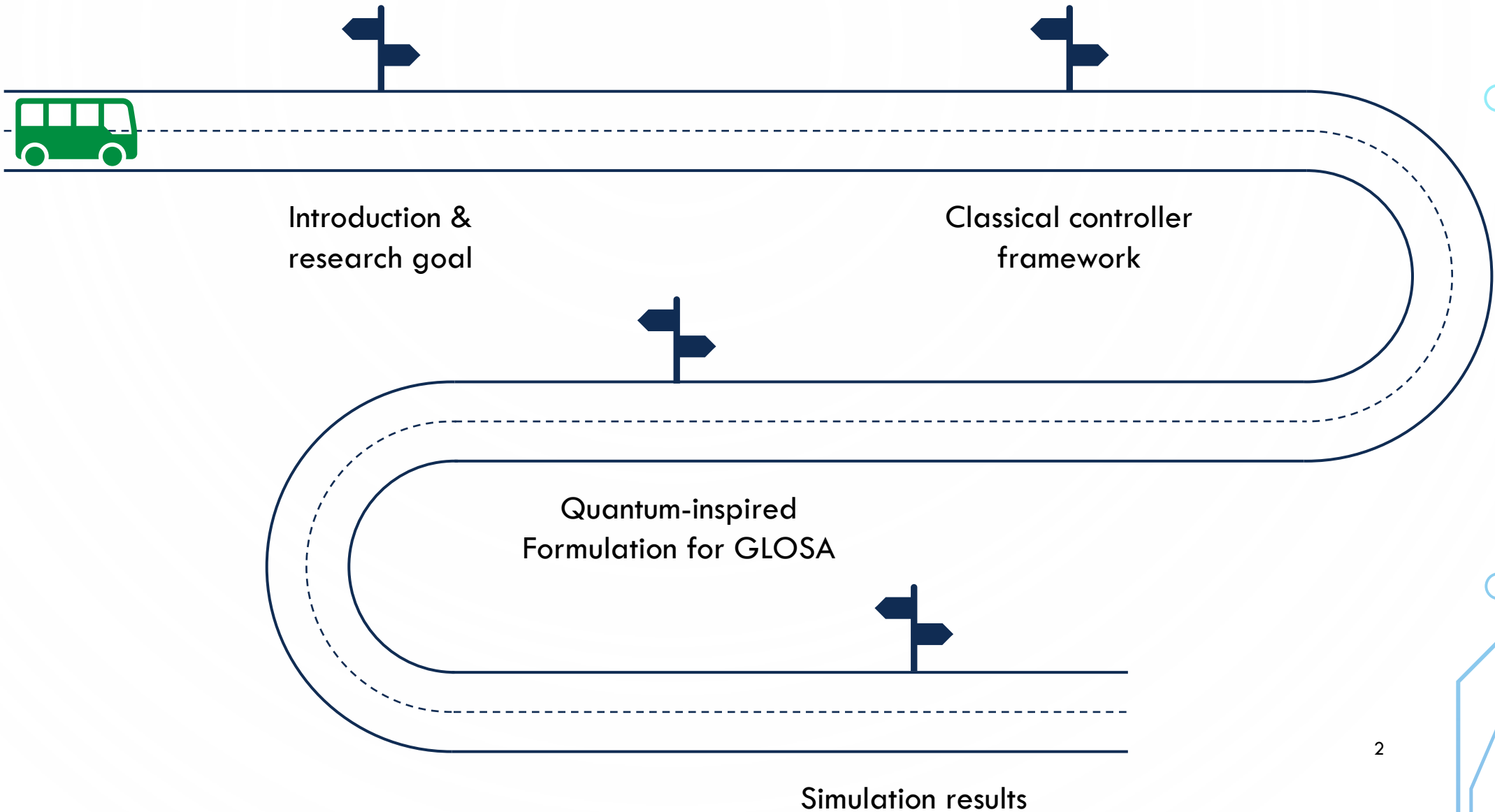
Leonardo Lavagna, Daniele Vignarca, Stefano Arrigoni,
Edoardo Sabbioni, Antonello Rosato, Massimo Panella

Presented by
Leonardo Lavagna & Daniele Vignarca

12 June 2026 – ITS Session

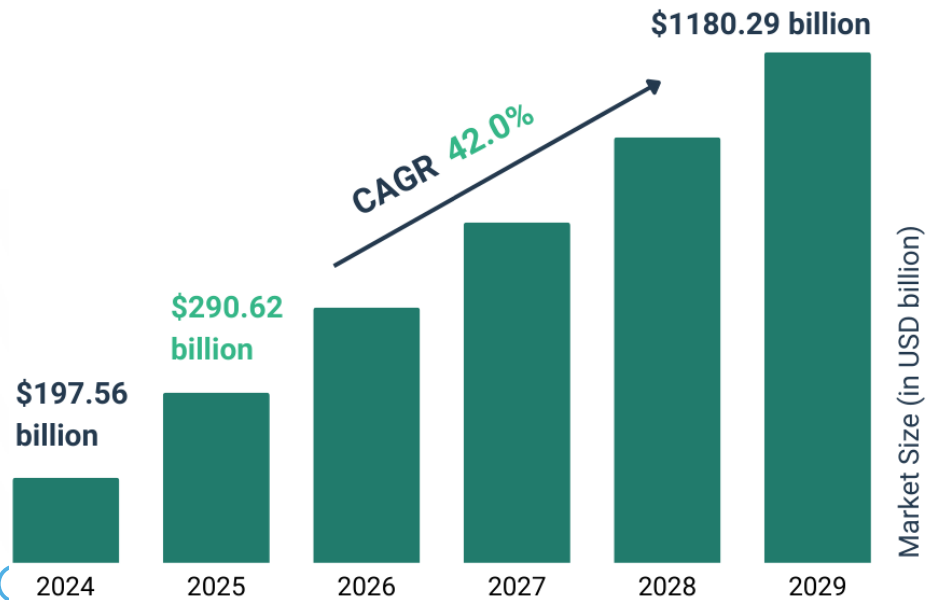


OUTLINE



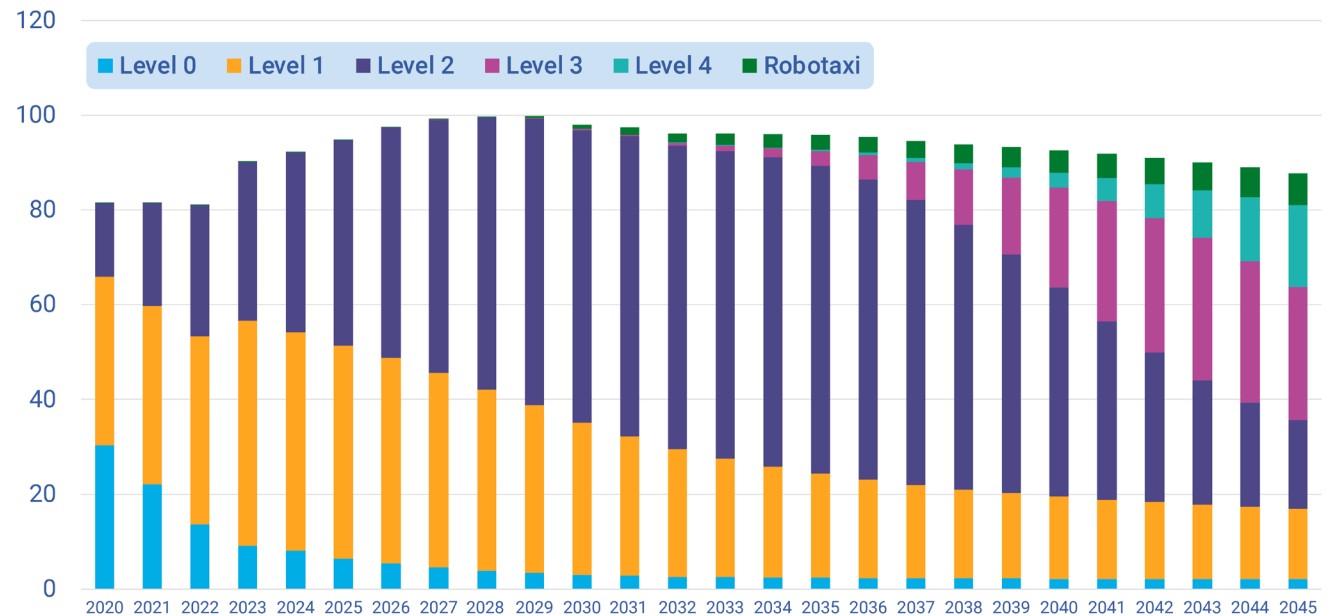
CONNECTED ADAS – FRAMEWORK

Connected And Autonomous Mobility Vehicles Global Market Report 2025



Source: The Business Research Company

Autonomous Cars Forecast by Society of Automotive Engineers (SAE) Levels of Autonomy 2020-2045 (million units)



Source: IDTechEx Research



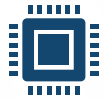
Massive deployment of **ADAS** in the next decade

RESEARCH GOAL



Quantum framework for GLOSA application

- ✓ VEHICLE MODEL
- ✓ CONSTRAINTS
- ✓ TRAFFIC LIGHT INTERACTION



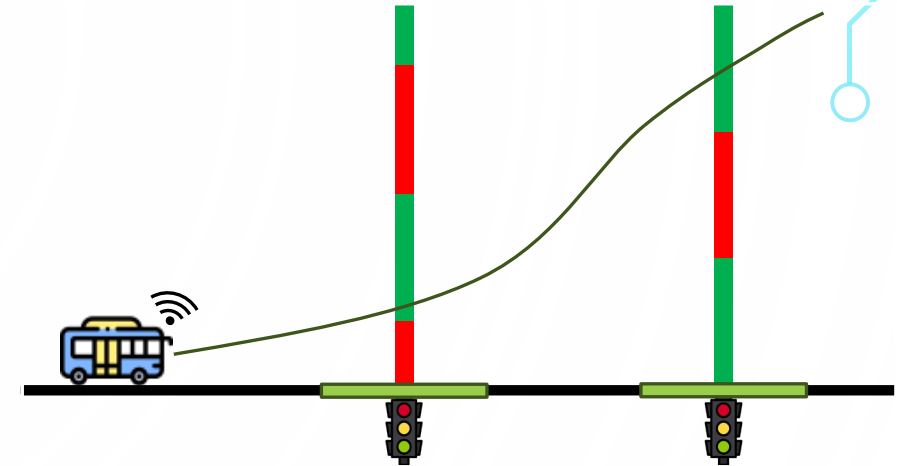
VQAs & PQCs to approximate solution of ODE chain



Feasibility using real-world data



Assessment against classical benchmark



GitHub available

GREEN WAVE OPTIMIZATION

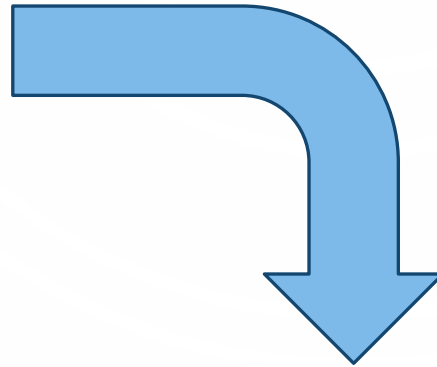
Eco-driving solutions aim to adjust:



Vehicle speed



Traffic light phase



- GLOSA solved with classical approaches (rule-based, MPC, etc.)
- Quantum machine learning rising as alternative paradigm

GREEN WAVE OPTIMIZATION

Classical MPC benchmark

$$\min_u J = \int_{t_0}^{t_h} l(s(t), a_x(t), u(t), t) dt$$

$$l = \frac{u(t)}{u_{max}} + \frac{a_x(t)}{A_{x,max}} + \frac{s_{max} - s(t)}{s_{max}}$$

passengers
comfort

energy
consumption

covered
distance



MPC solved through ACADO Toolkit

Discretization prediction horizon \rightarrow 1 s

GLOSA Model Predictive Control

Vehicle model

$$\dot{s}(t) = v(t)$$

$$\dot{v}(t) = a_x(t)$$

$$\dot{a}_x(t) = u(t)$$



Cost function

- $\min u(t)$
- $\min a_x(t)$
- $\max s(t)$



Constraints

- Traffic lights
- Bus stops
- Electric Motor
- Speed
- Comfort



Online data



MPC previous work

REAL WORLD DATASET



- 5.2 km-long portion of circular Milan trolley-bus line
- Most of the path is on a dedicated lane for buses

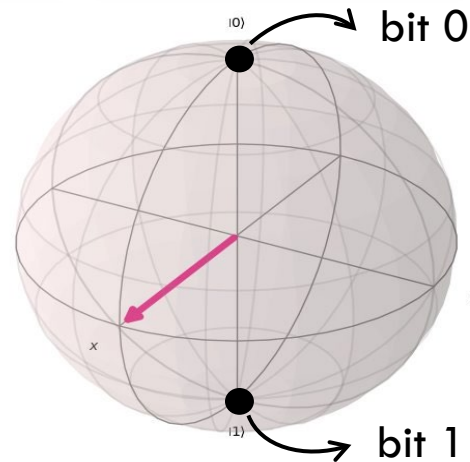


- 30 connected traffic lights → 175 m avg. distance
- 16 bus stops on the path → 335 m avg. distance

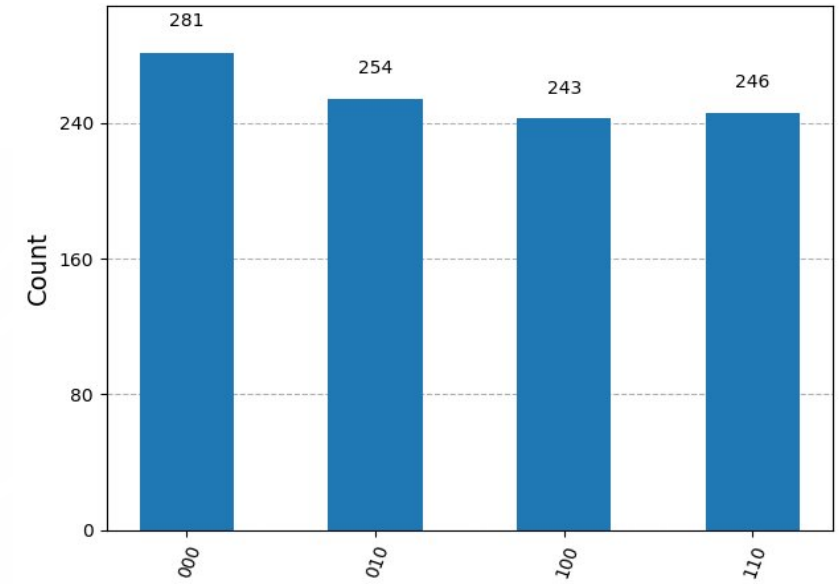
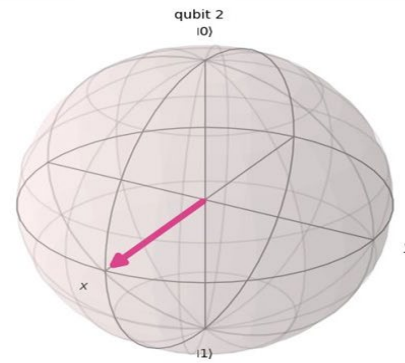
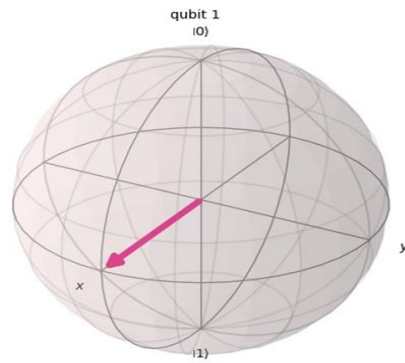
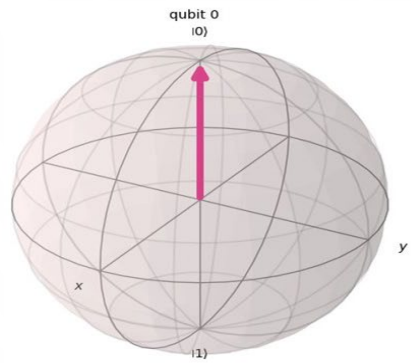
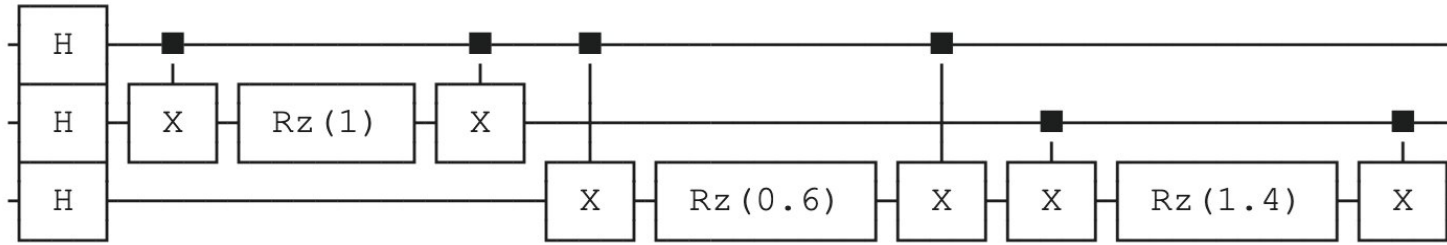
QUANTUM COMPUTING

Classical computers encode and process information as **bits**: 0 or 1.

Quantum computers use **qubits** (i.e., elements of a projective complex line = the Bloch sphere), whose state (vector) can encode several possibilities before readout.



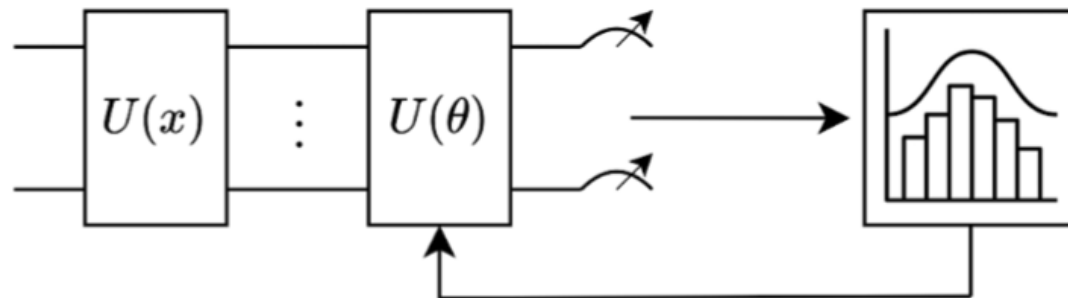
CIRCUIT MODEL



KEY IDEAS

We can leverage:

- **Superposition:** many candidate states can be represented at once.
- **Entanglement:** variables can be coupled (correlated) in non-classically achievable ways.
- **Interference:** wrong answers can be suppressed, useful answers amplified.
- **Hybridization:** quantum computers can be incorporated in trainable classical components to boost machine learning applications.



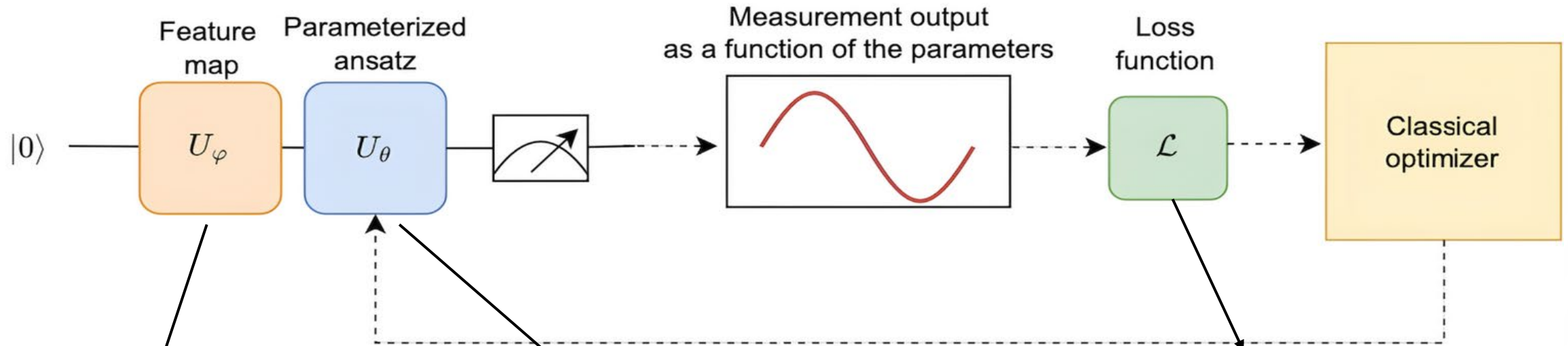
PROPOSED METHODOLOGY

The research problem combines **tree structures**:

- vehicle dynamics
- traffic-light schedule
- physical and comfort constraints

The proposed quantum approach connects them in **one framework** solving at the same time the corresponding equations of motion, optimizing the velocity profile to match a green wave while satisfying the constraints.

PROPOSED METHODOLOGY



$$|0 \times 0\rangle \otimes \mathbf{1} + R_y(\varphi(u))$$

$$(1 - p) \cos(\theta t) + p \cos(\theta t + \varphi(u))$$

Constraints

- Traffic lights
- Bus stops
- Electric Motor
- Speed
- Comfort

SIMULATION PARAMETERS

Epochs: 200

Learning rate: $5 \cdot 10^{-4}$

Order: 2

$v_{max} = 15 \text{ m/s}$

$a_{max} = 0.5 \text{ m/s}^2$

$u_{max} = 0.2 \text{ m/s}^3$

$a_{v,max} = 0.5 \text{ m/s}^2$

λ_{back} : 200

λ_{smooth} : 50

λ_{match} : 50

λ_{mono} : 200

Number of training epochs

Learning rate for optimizer

Depth of the quantum feature map

Maximum allowed velocity

Maximum longitudinal acceleration

Maximum control increment

Maximum lateral acceleration

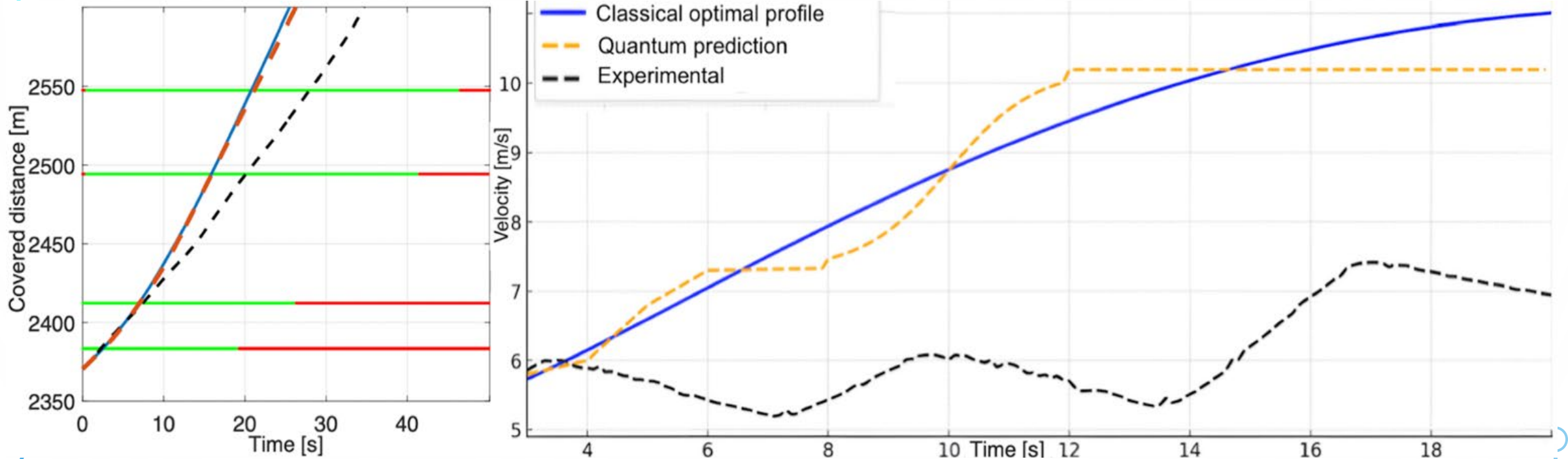
Penalty for negative velocity

Penalty encouraging smooth velocity

Penalty to match ground-truth

Optional penalty for monotonicity

SIMULATION RESULTS



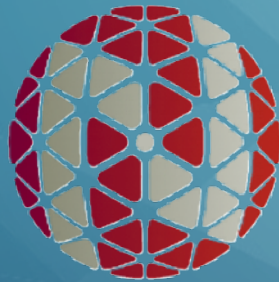
PROS & CONS

Advantage	Disadvantage
You can take into account “future” stoplight states via entanglement	Limited quantum hardware
You can have a global view of the route/infrastructure via superposition	No real-time predictions/updates (quantum simulations are slow)
More realistic velocity profiles (no “bang-bang” controls)	No established communication channels
You can leverage all the information (stoplights, dynamics, constraints) within a single process	

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Thank you for your attention



NESYA
LABORATORY



leonardo.lavagna@uniroma1.it



POLITECNICO
MILANO 1863

DEPARTMENT
OF MECHANICAL
ENGINEERING

daniele.vignarca@polimi.it

