Energy efficient driving in dynamic environment

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Virtual Vehicle

virtual vehicle

Future Vehicle Technology

Energy efficient driving in dynamic environment:

Considering other traffic participants and overtaking possibility

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ITEAM project

Interdisciplinary Training Network in Multi-Actuated Ground Vehicles (MAGV)

The main target of the ITEAM project is to establish and sustainably maintain the European training network with high grade of interdisciplinarity, which will train strong specialists skilled in research and development of novel technologies in the field of multi-actuated ground vehicles (MAGV)

three research clusters:

- "MAGV integration",
- "Green MAGV",
- "MAGV Driving Environment"

Trainings:

- basic research,
- applied research, and
- experimentations.

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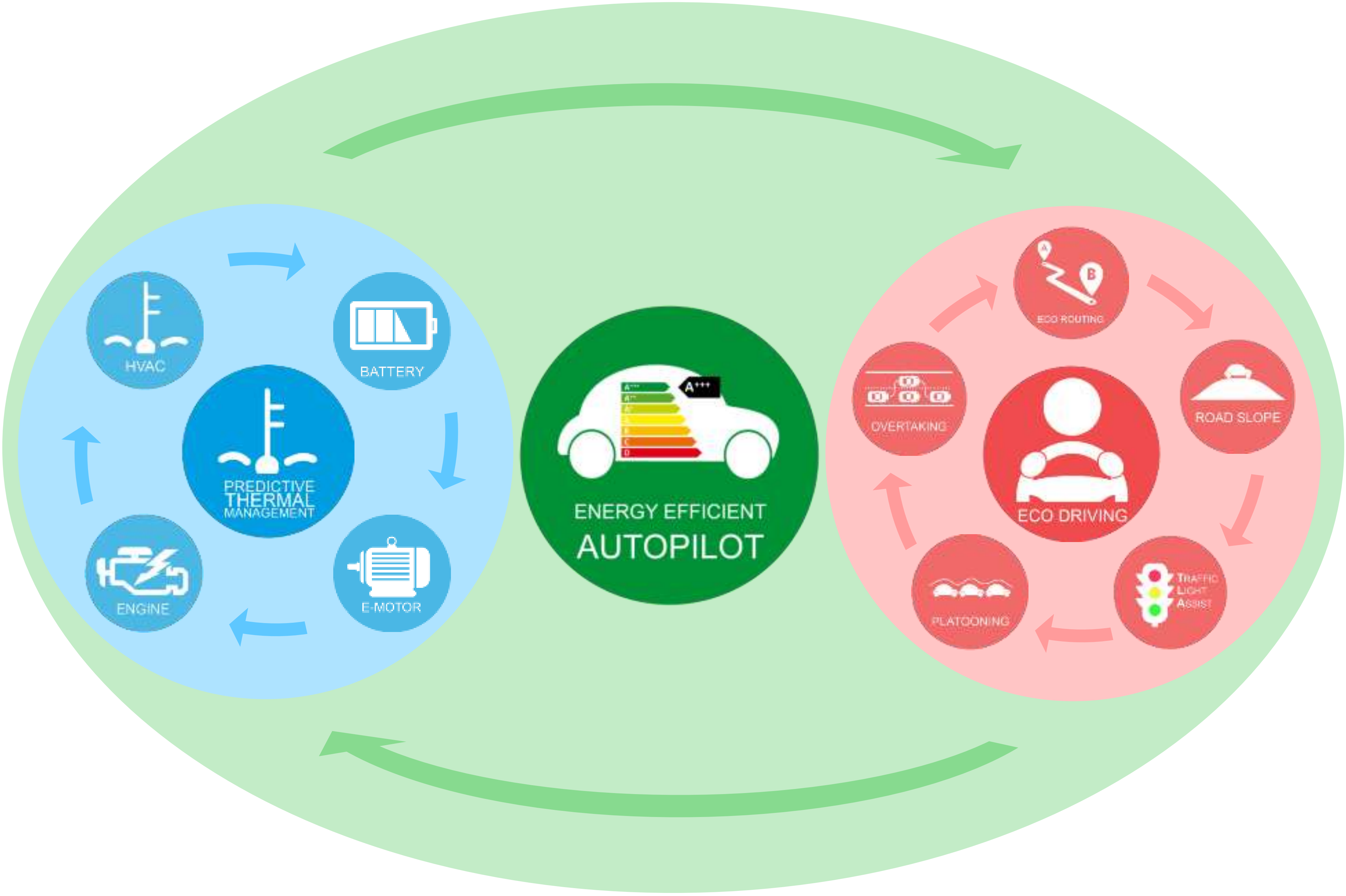

HVAC
BATTERY
PREDICTIVE
THERMAL
MANAGEMENT
ENGINE
E-MOTOR
ENERGY EFFICIENT
AUTOPILOT
ECO ROUTING
OVERTAKING
ROAD SLOPE
ECO DRIVING
PLATOONING
TRAFFIC
LIGHT
ASSIST

Ecodriving: Optimal Speed Trajectory Planner

Controller task:

- Plan speed trajectory of a vehicle from point A to point B using the least energy while complying with all constraints and enduring all disturbances

Constraints:

- Traffic lights (V2I, Cloud, Visual sensor)
- Traffic signs (stop sign, speed limits, etc.)
- Road conditions (curvature, low friction, etc.)
- Vehicle constraints (acceleration, power, battery State-of-Charge, etc.)
- Charging or resting time
- Travel time

Disturbances:

- Weather change (temp, air density, etc.)
- Road (slope, slippery road, etc.)
- Traffic (leading vehicle, traffic jam,etc.)

Controller outputs:

- Propulsion torque (Multi-actuated vehicle)
- Human-machine-interface (HMI)
- Steering (automated vehicle)

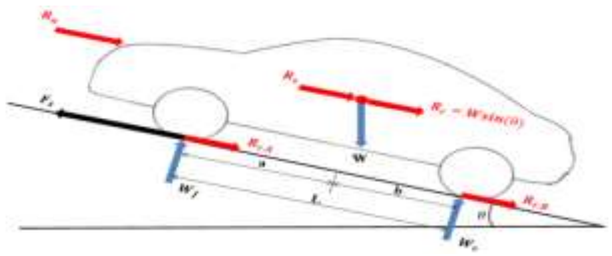
Controller inputs:

- Vehicle state observers (position, speed, batt SOC, power consumtion, etc.)
- Cloud services (Weather conditions , GIS, etc.)
- Environment perception (obstacles, speed limits, traffic lights, etc.)
- Vehicle-to-X communication (V2X)
- Human-machine-interface (HMI)

Challenges:

- Nonlinearity
- Realtime computation vs precision
- Course of dimesionality
- Dynamic constraints

Vehicle model: Particle-mass



force balance

$$\dot{s} = v\,, \qquad (1)$$

$$\dot{v} = \frac{F_m(t)}{m} - \frac{F_r}{m}\,, \qquad (2)$$

$$F_r = \frac{1}{2}\rho_a c_d A_f v(t)^2 - c_r m g cos\left(\alpha\left(s(t)\right)\right) - m g sin\left(\alpha\left(s(t)\right)\right)\,, \qquad (3)$$

$$F_m(t) = \frac{k T_m \eta^{sign(T_m(t))}}{r_w}, \qquad \omega(t) = \frac{k v(t)}{2 r_w \pi}\,. \qquad (4)$$

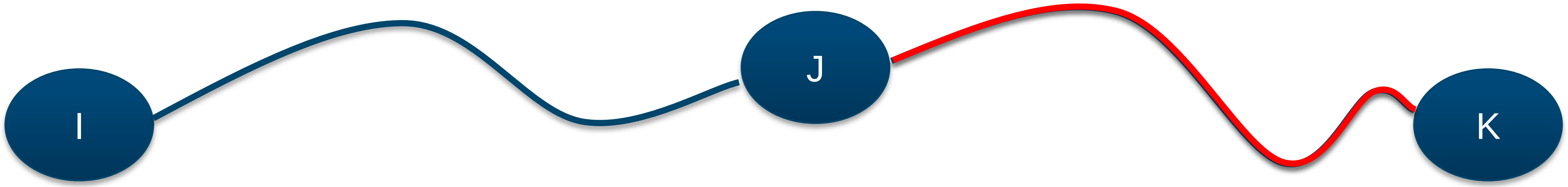
Cost function

$$E_{min} = \min_{T_m} \int_0^T \left(\omega(t) T_m(t) + P_{aux}\right) dt\,. \qquad (5)$$

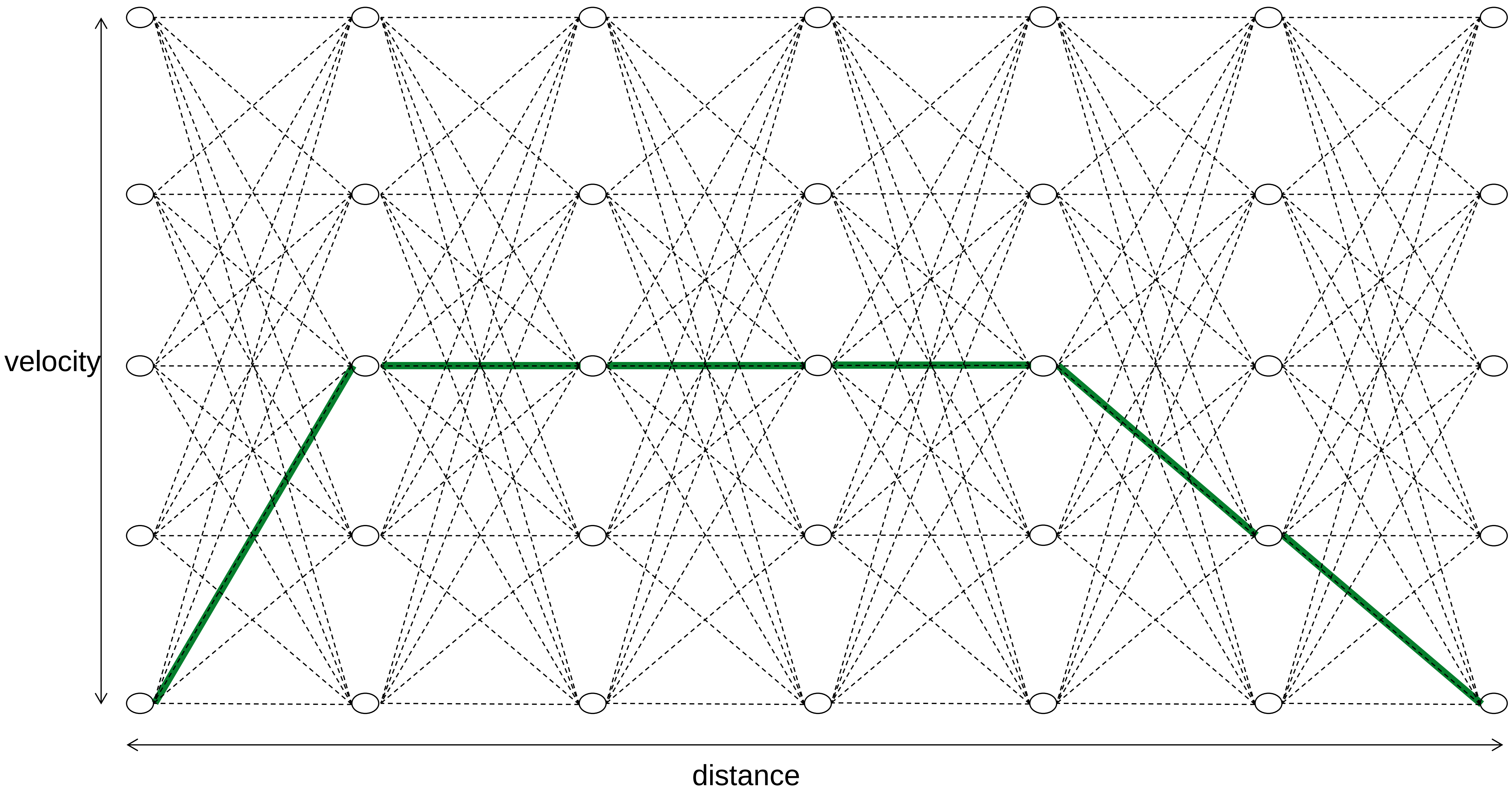
Optimization approach: Dynamic programming

Principle of Optimality

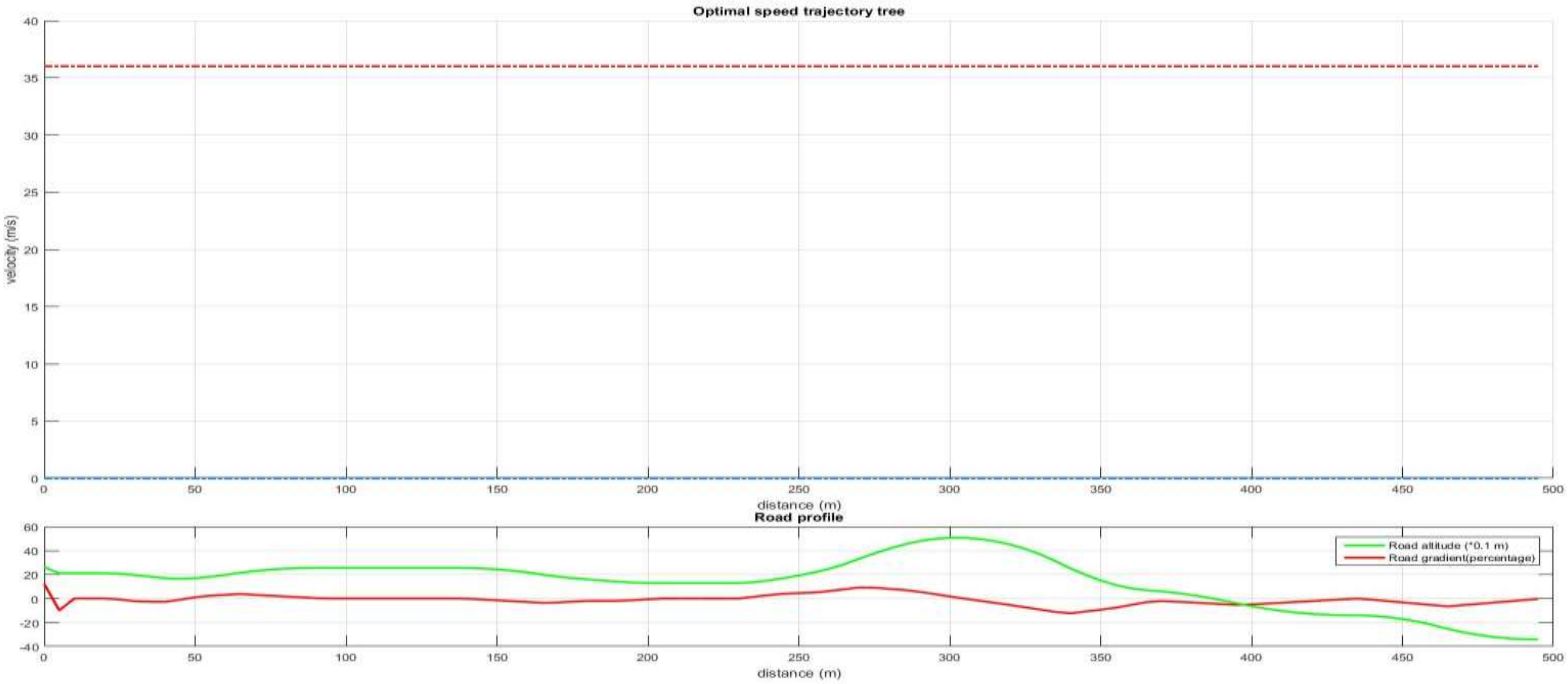
If node J is on the optimal path from node I to node K, then the optimal path from J to K also falls along the same route.



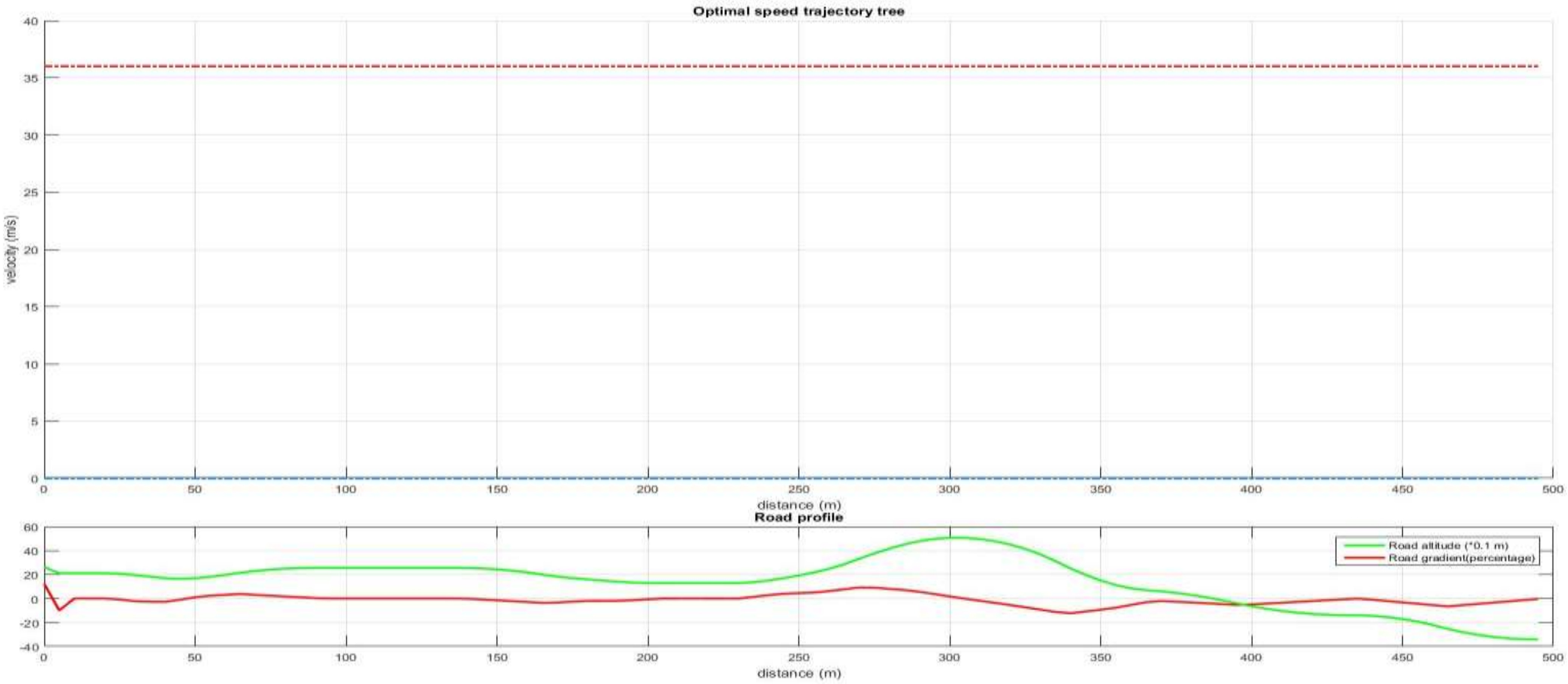
Optimization approach: Dynamic programming



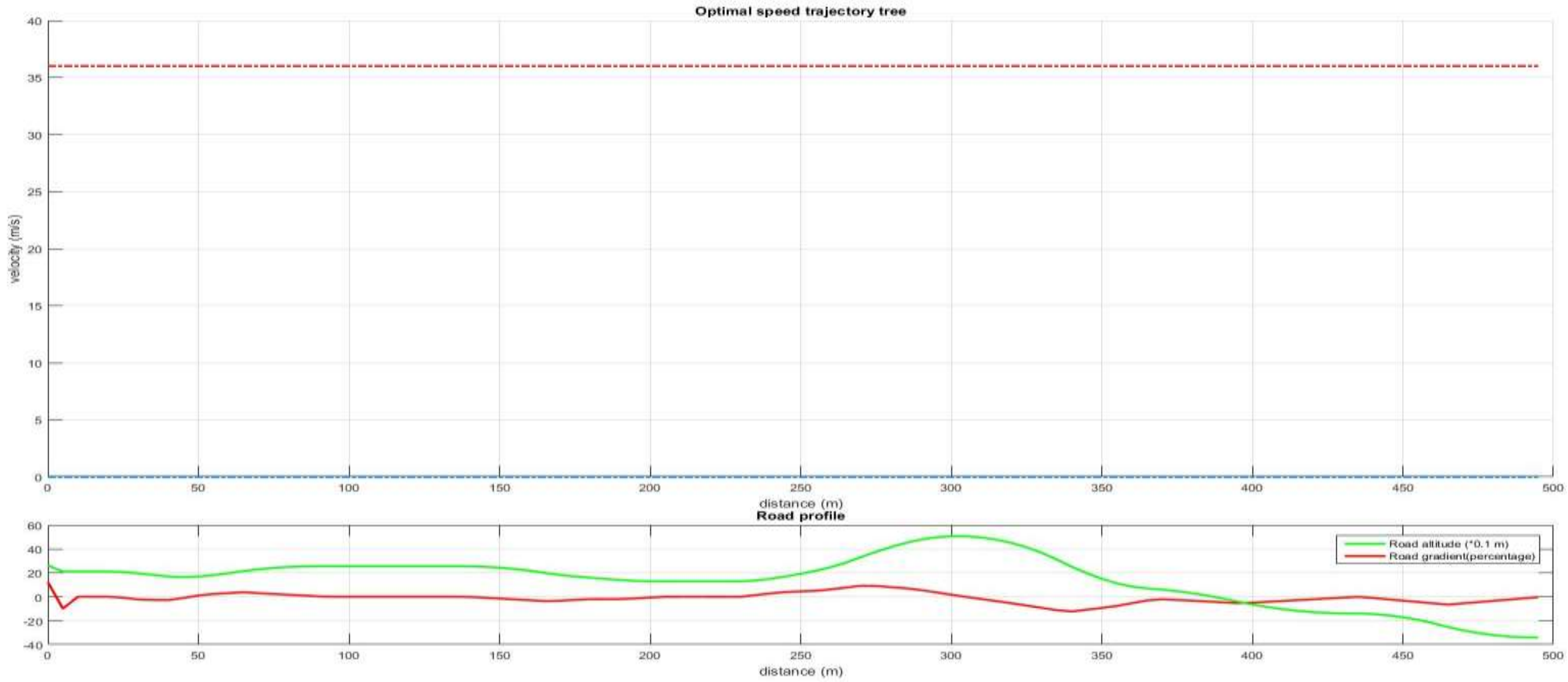
Backward DP animation



Forward DP animation



A* animation

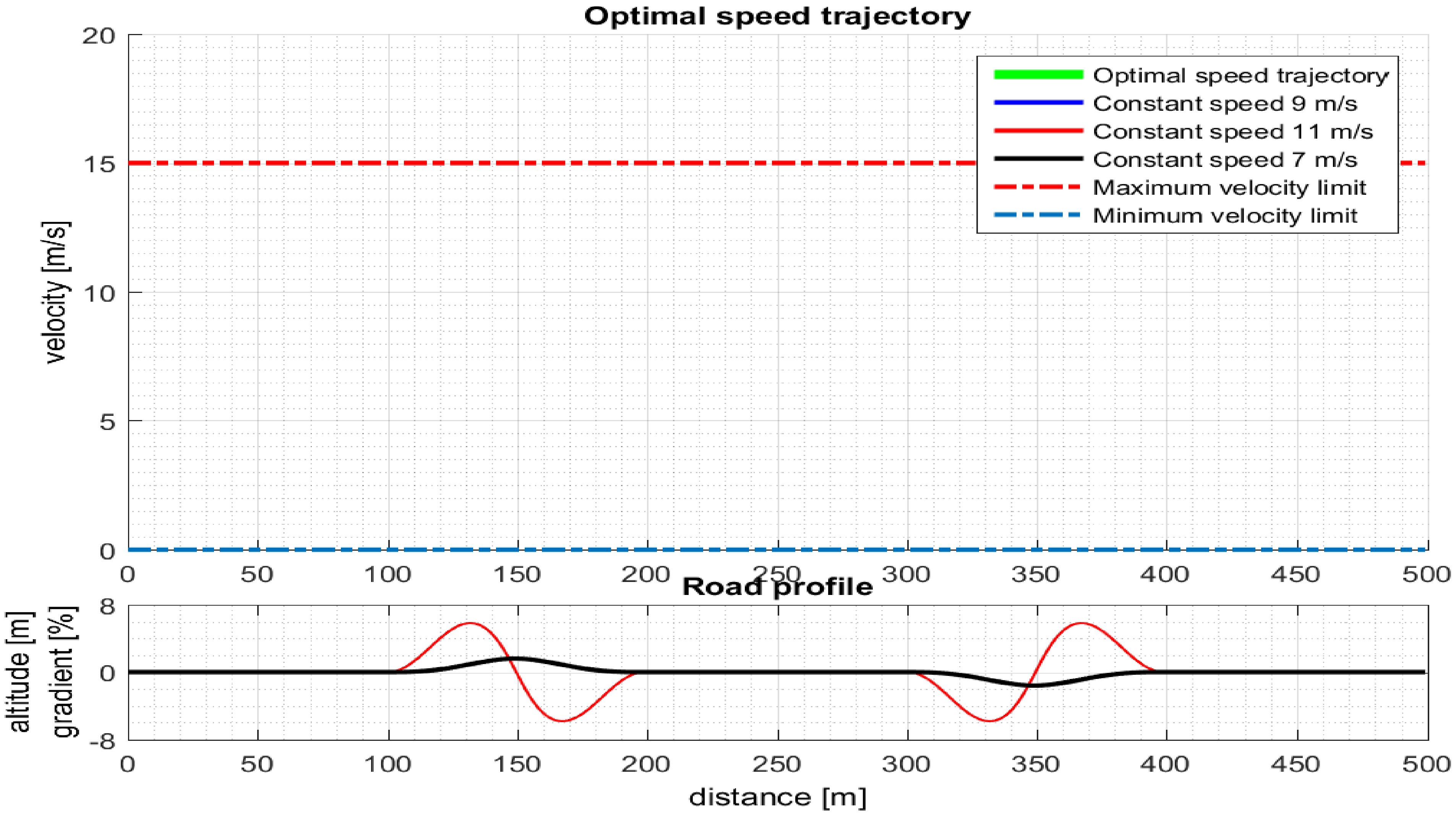


Optimal speed trajectory tree
velocity (m/s)
distance (m)
Road profile
Road altitude (*0.1 m)
Road gradient(percentage)
distance (m)

Initial results

- **Constant speed driving vs Ecodriving**
- **Existing vs proposed overtaking approach**
- **Influence of the road gradient**
- **Influence of the speed difference**

Initial results: Constant speed driving vs Ecodriving



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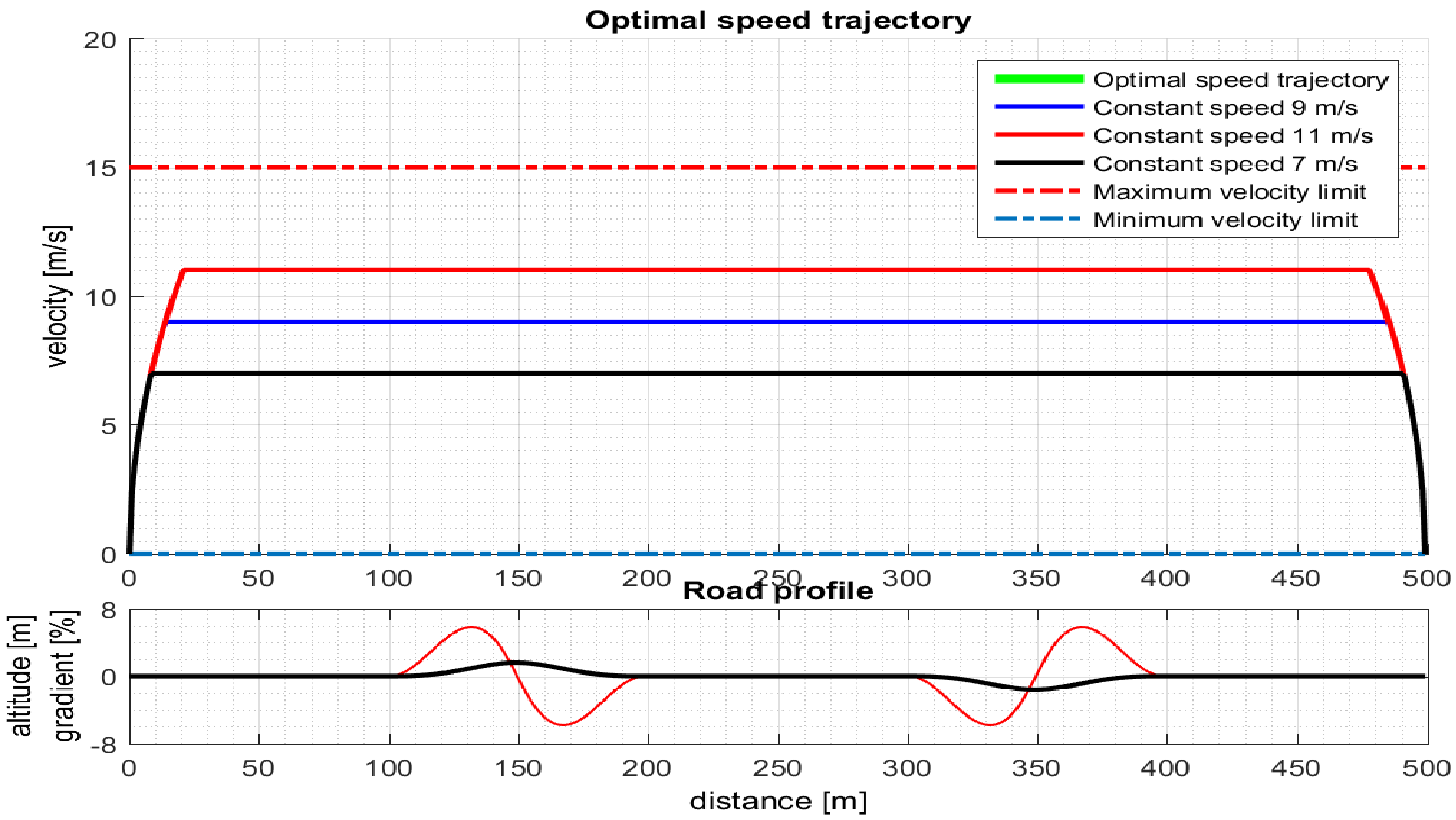
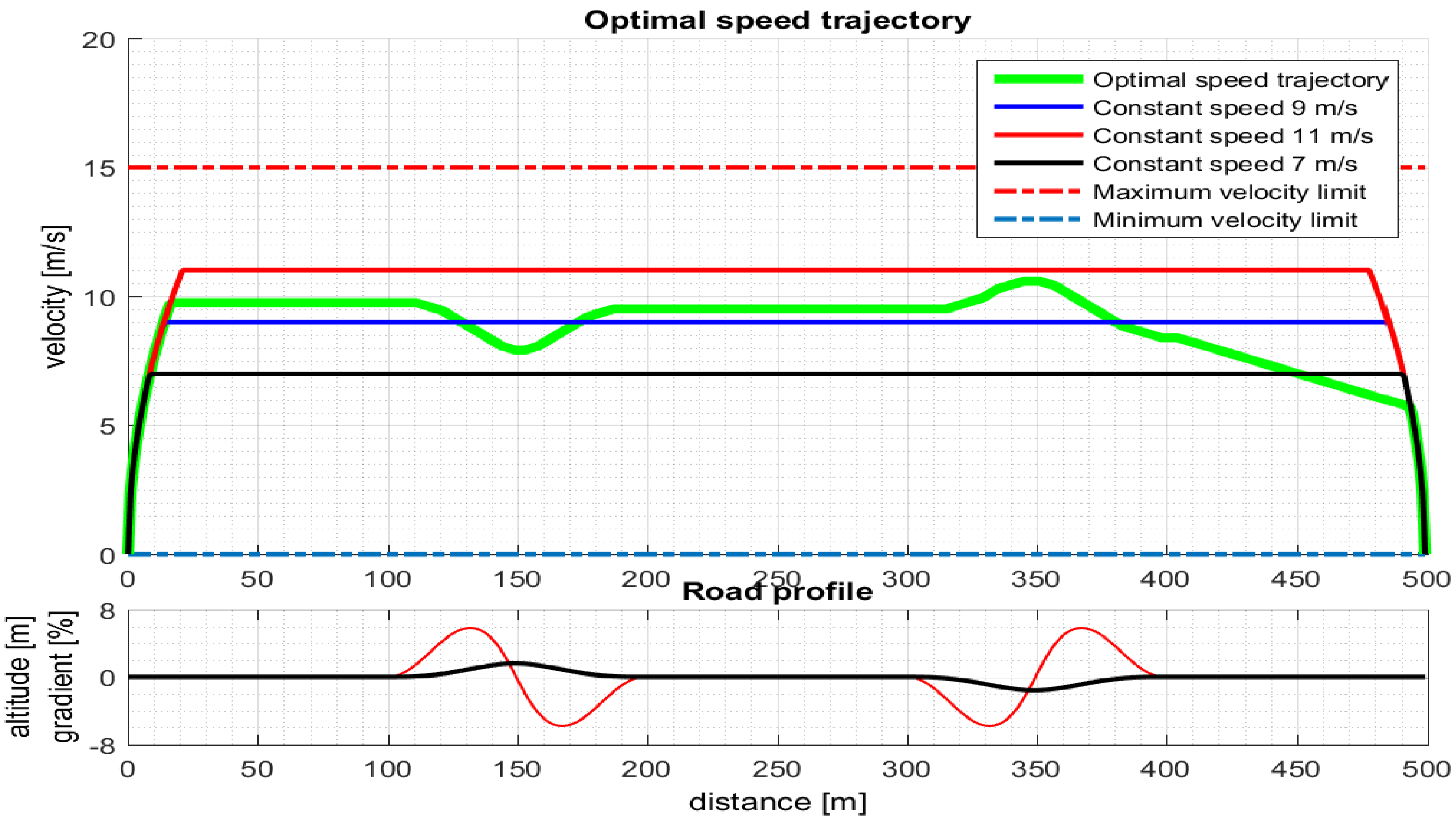


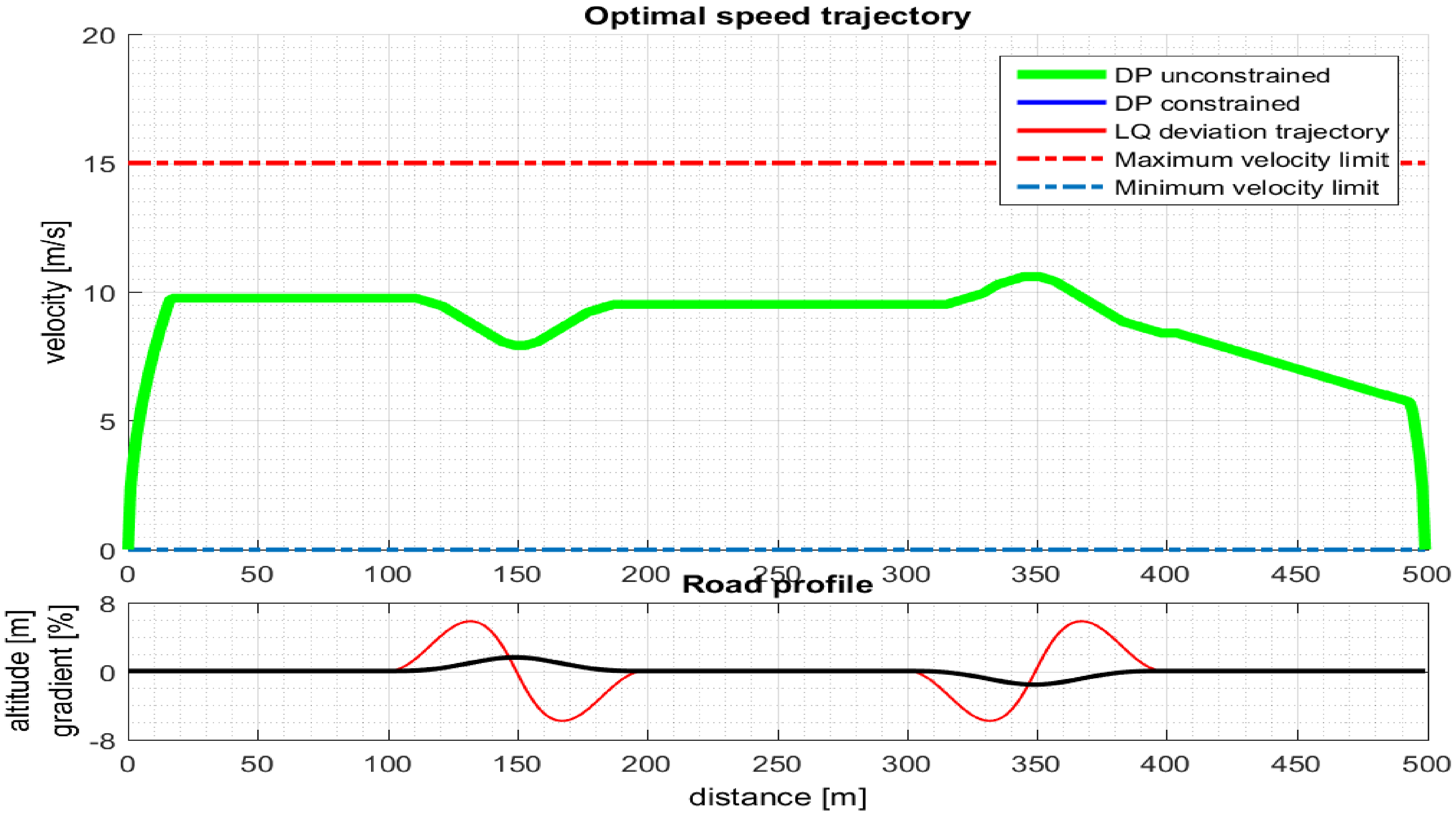
Initial results: Constant speed driving vs Ecodriving



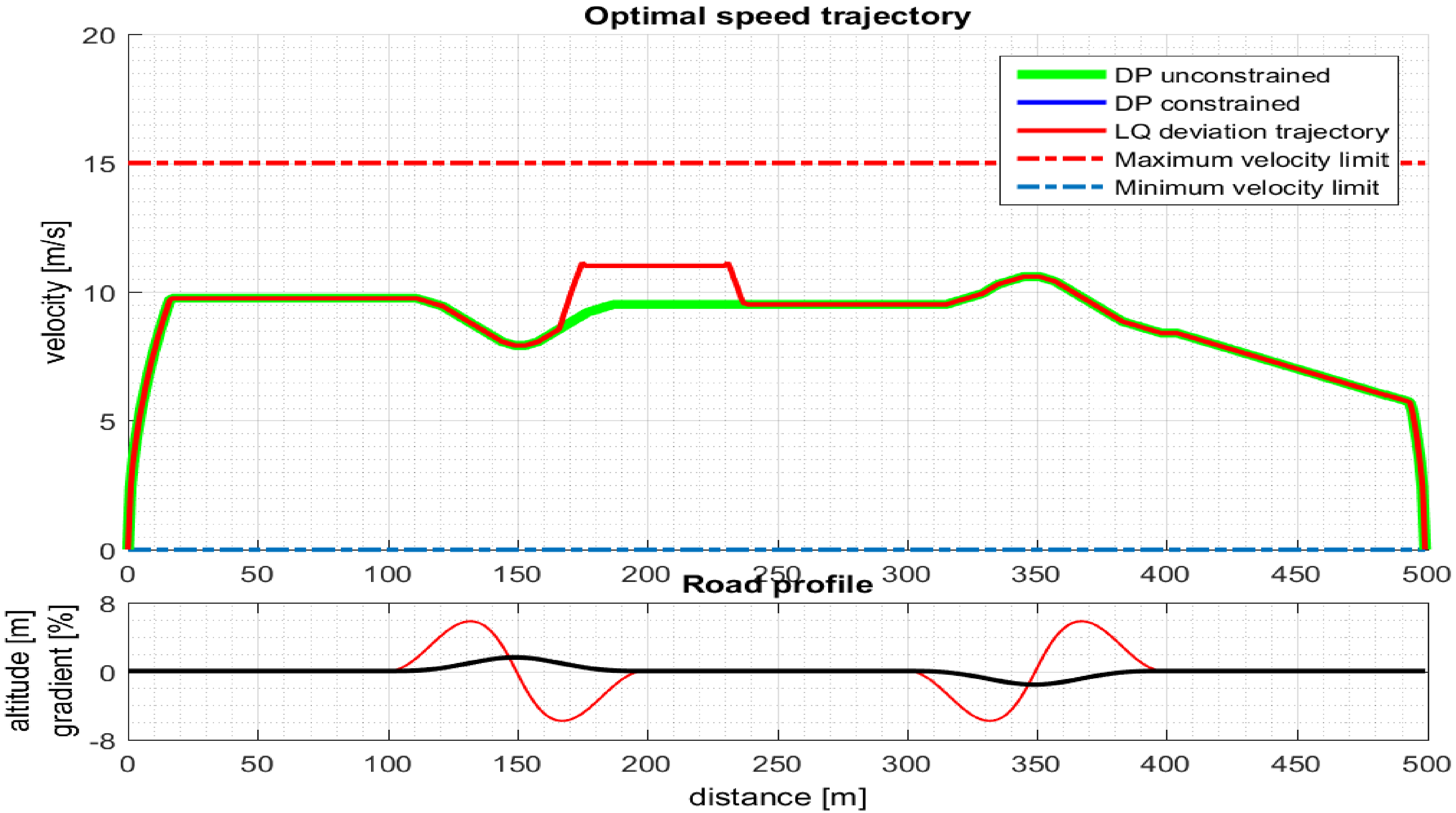
Initial results: Constant speed driving vs Ecodriving

	Energy used [kJ]	difference [%]	Time travelled [s]	time difference [%]
Optimal traj.	213.87	0	59.25	0
speed 9 m/s	231.68	+8.3	58.49	-1.28
speed 11 m/s	237.98	+11.3	49.06	-17.20
speed 7 m/s	237.97	+11.3	73.75	+24.47

Initial results: Existing vs proposed overtaking approach



Initial results: Existing vs proposed overtaking approach



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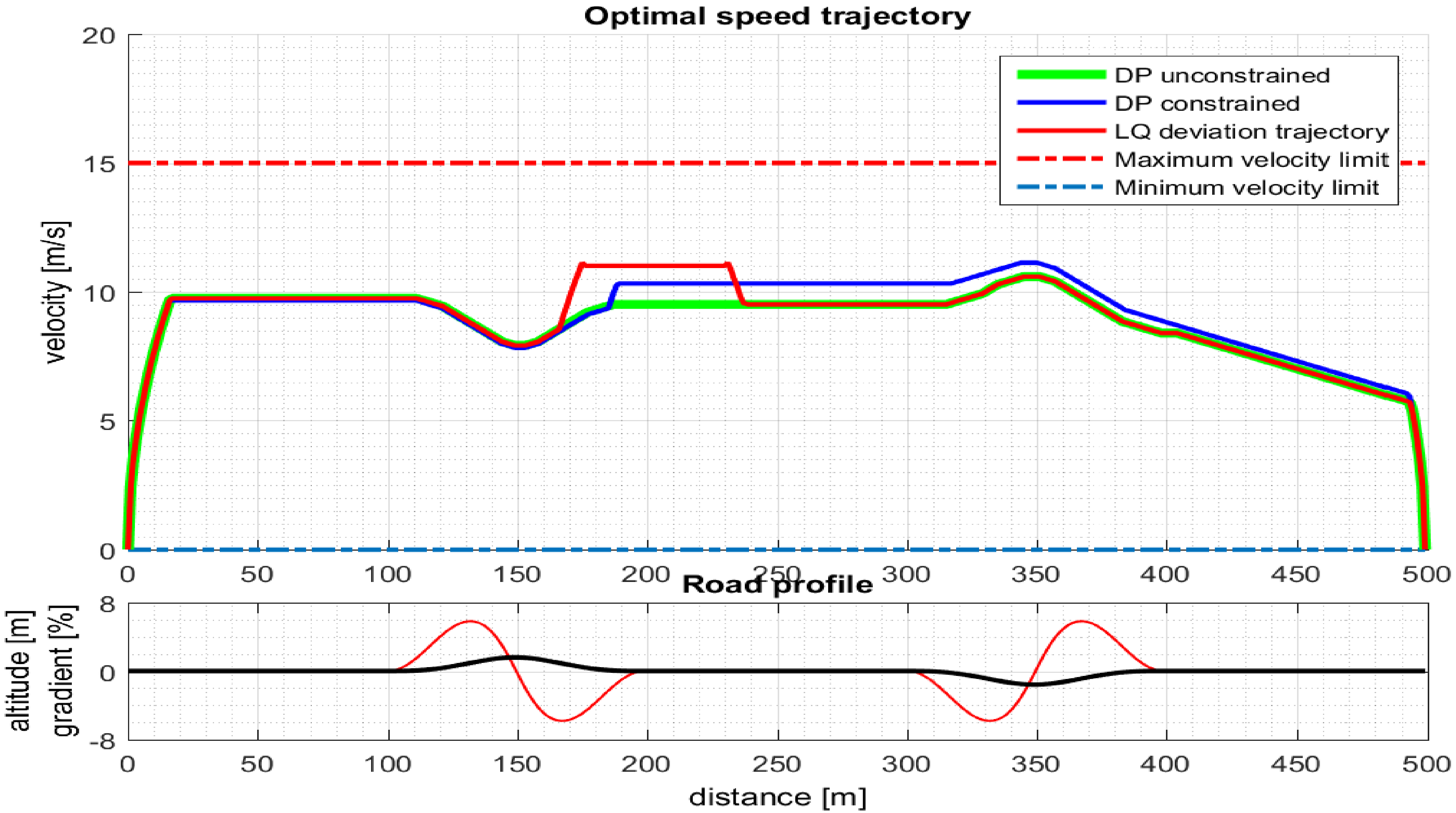
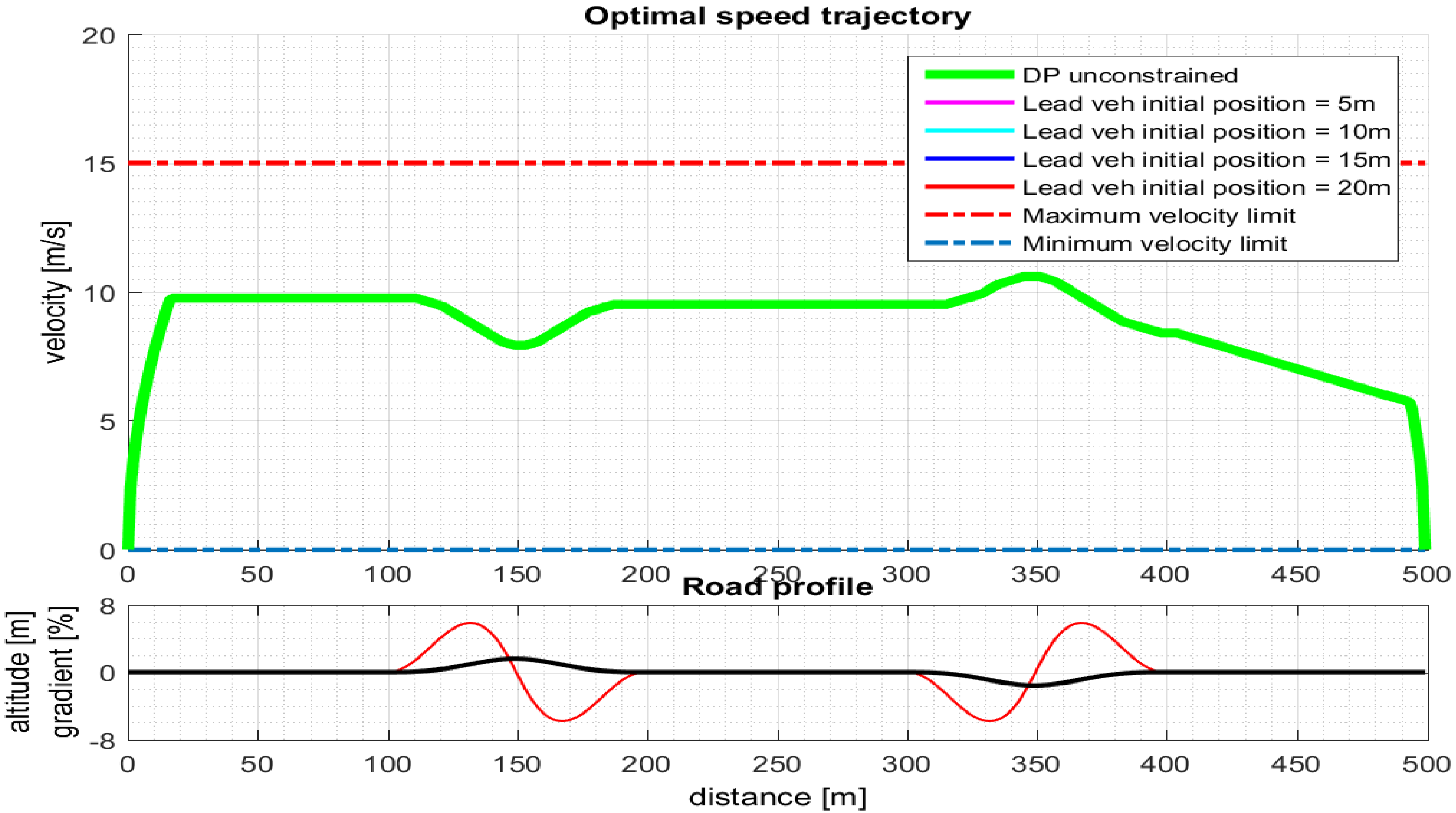


Initial results: Existing vs proposed overtaking approach

	Energy used [kJ]	difference [%]	Time travelled [s]	difference [%]
Unconstrained	213.87	0	59.25	0
Constrained	215.45	+ 0.74	57.34	-3.23
LQ deviation	225.15	+ 5.27	58.27	-1.66

Initial results: Influence of the road gradient



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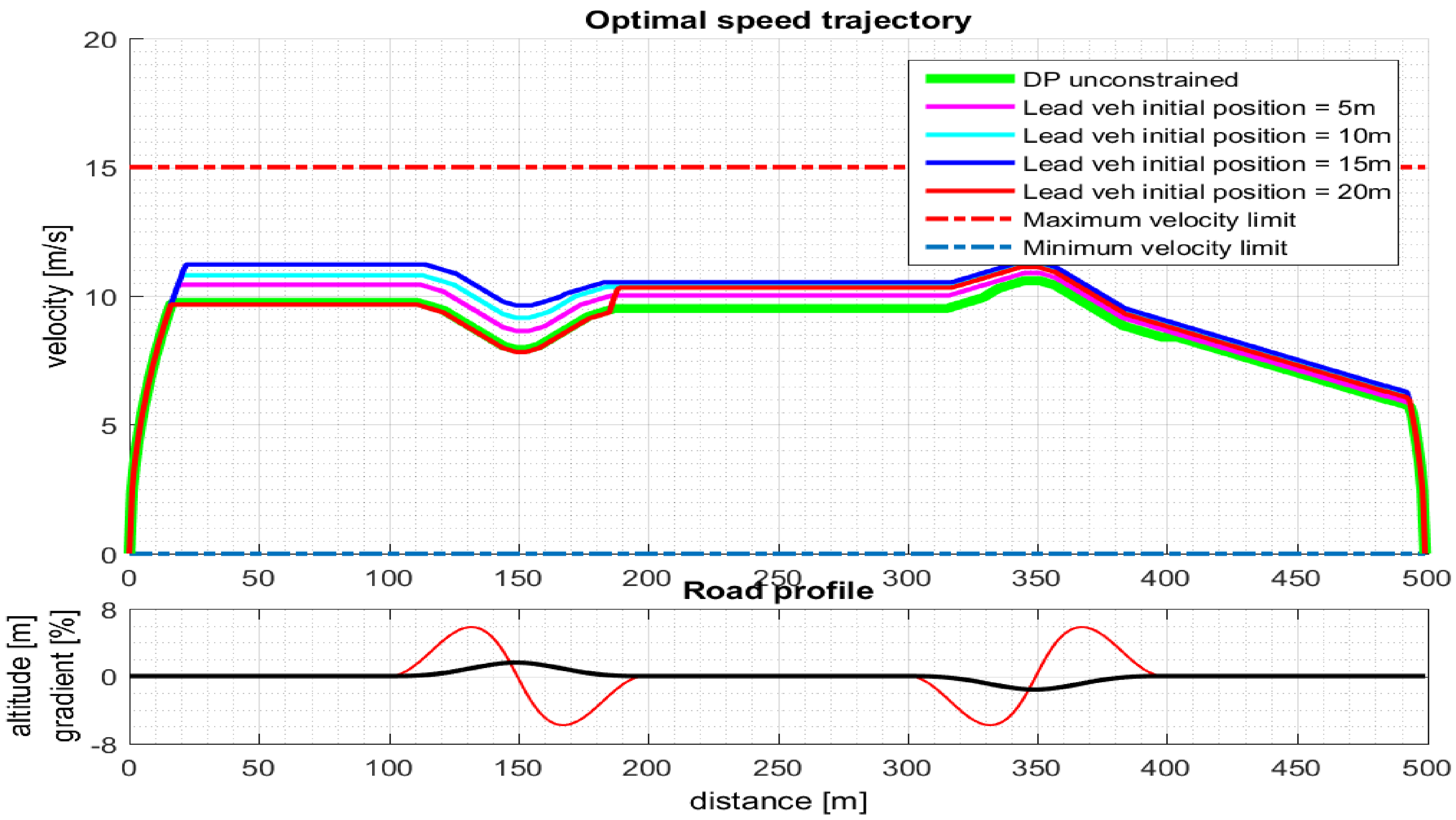
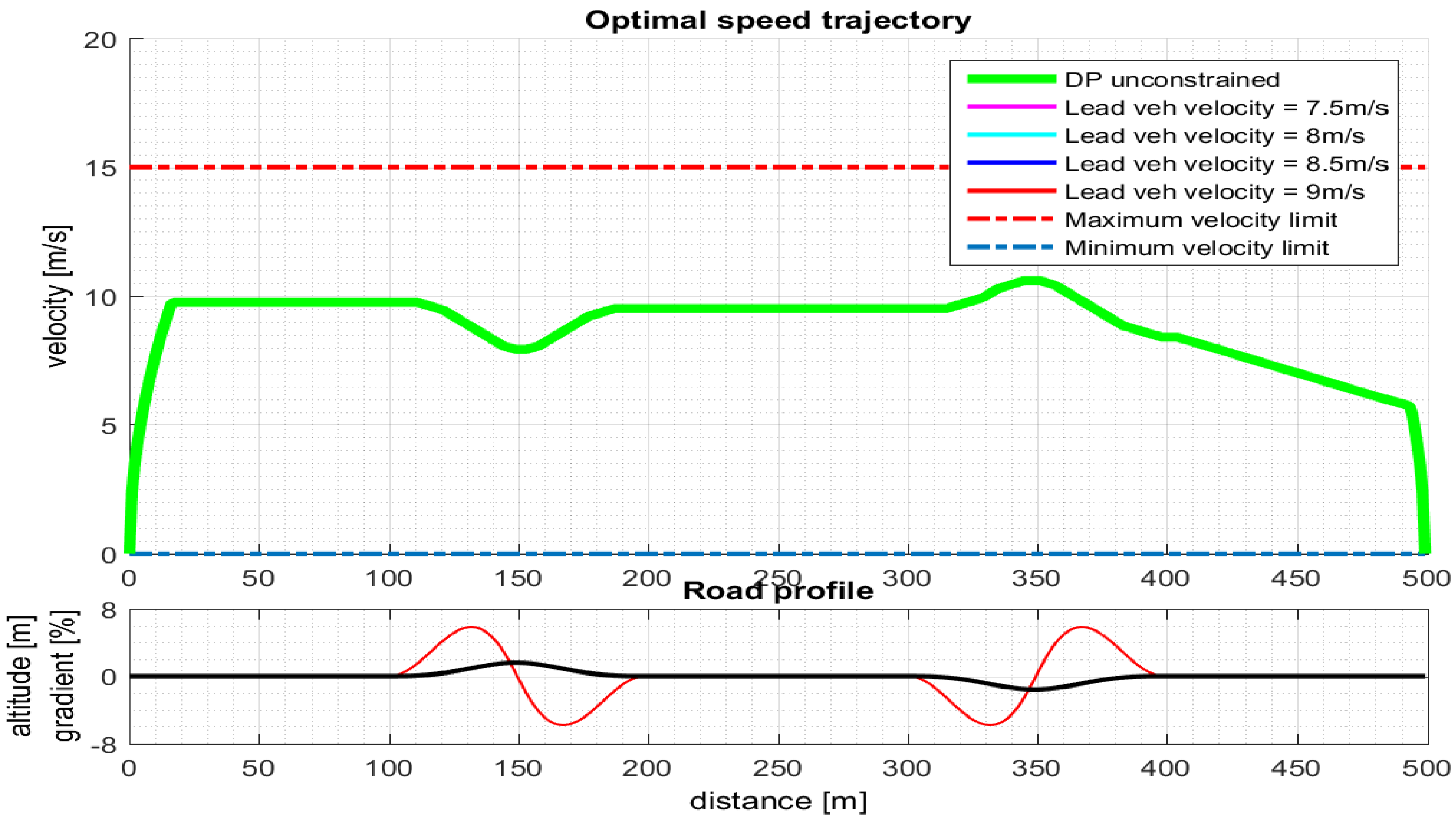


Initial results: Influence of the speed difference



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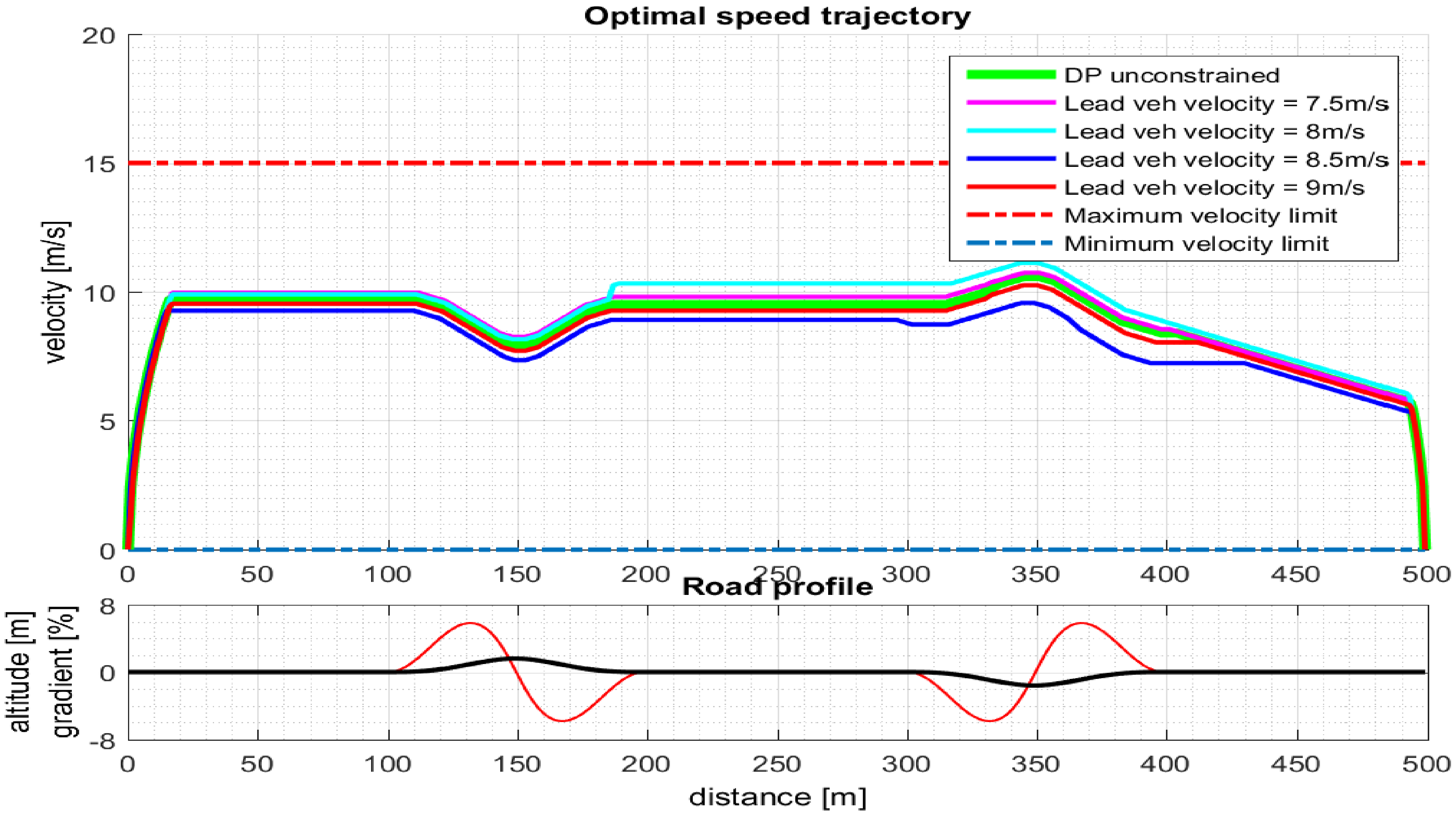

Future plans

- **Implement integration of other constrains into optimization problem (multiple vehicles, vehicles moving in other direction, traffic lights, etc.)**
- **Validate in simulation environment (CarMaker)**
- **Validate in demonstrator vehicle**
- **Integrate predictive thermal management**

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