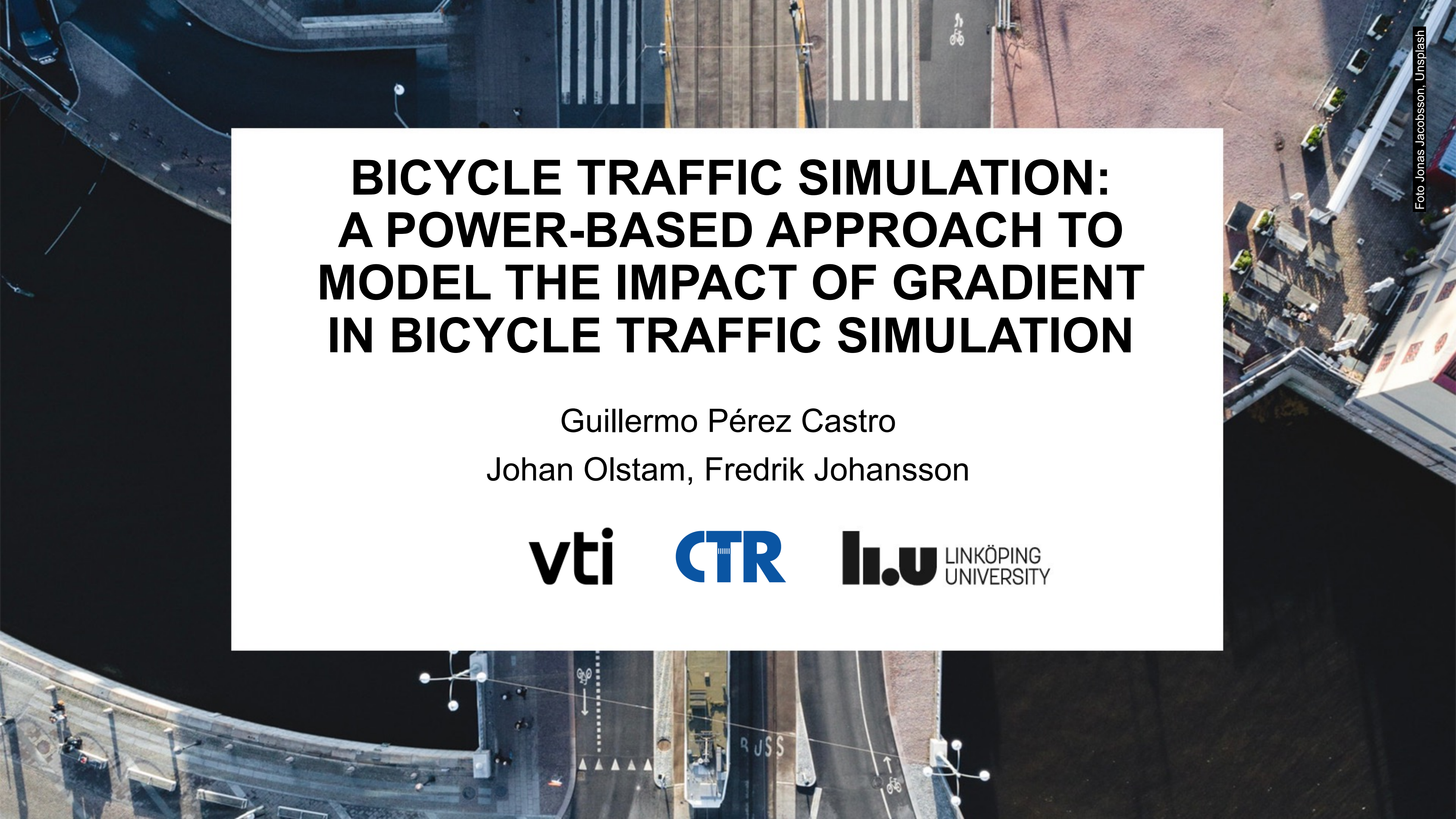

Foto Jonas Jacobsson, Unsplash

BICYCLE TRAFFIC SIMULATION: A POWER-BASED APPROACH TO MODEL THE IMPACT OF GRADIENT IN BICYCLE TRAFFIC SIMULATION

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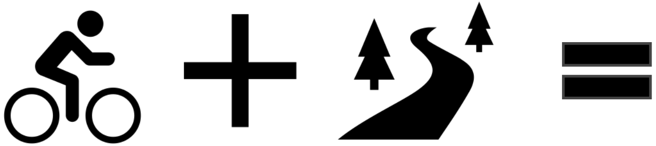
BACKGROUND

- We want more people cycling!

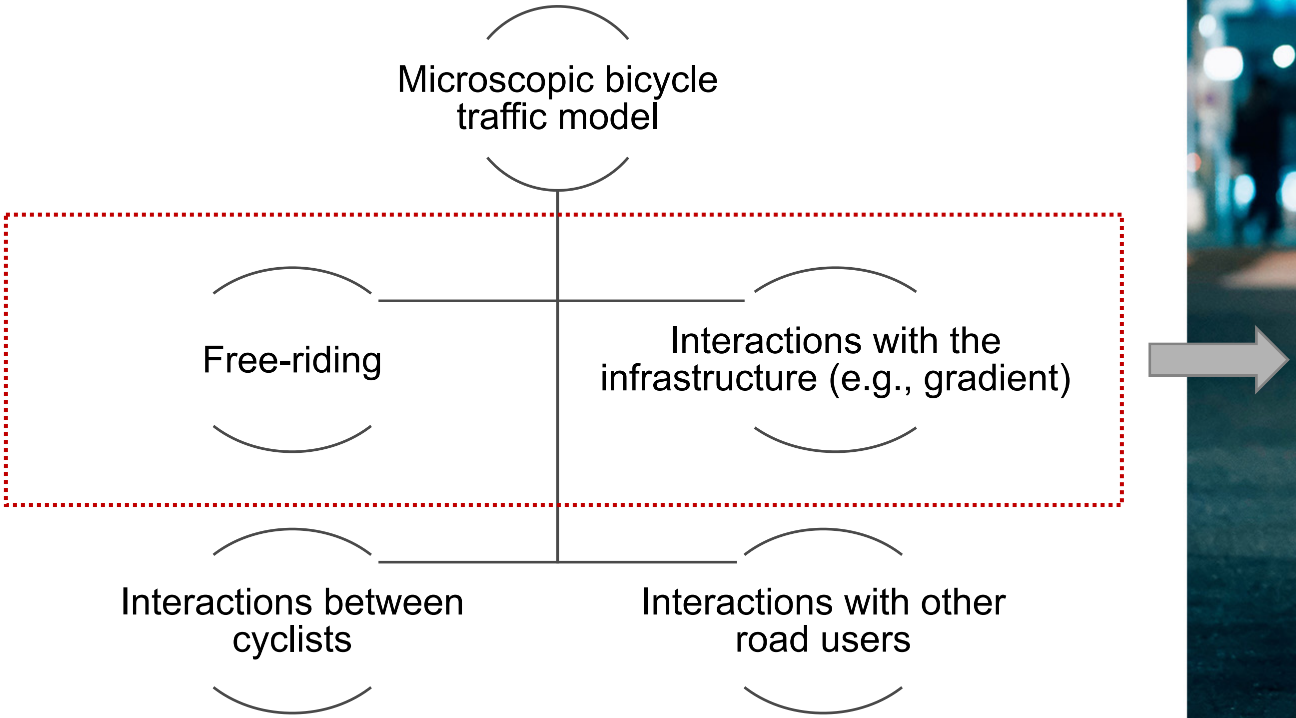
Lots of · Inadequate



Congestion
(Delays, Discomfort)

- PhD project on bicycle traffic simulation.
  - Need for traffic modelling support for bicycle traffic.
  - A microscopic traffic simulation approach .
    - High heterogeneity in bicycle traffic.
    - Scope: off-street bicycle path segments.

Purpose of the PhD project: to investigate, develop, and evaluate microscopic traffic models for simulating the behavior of cyclists.

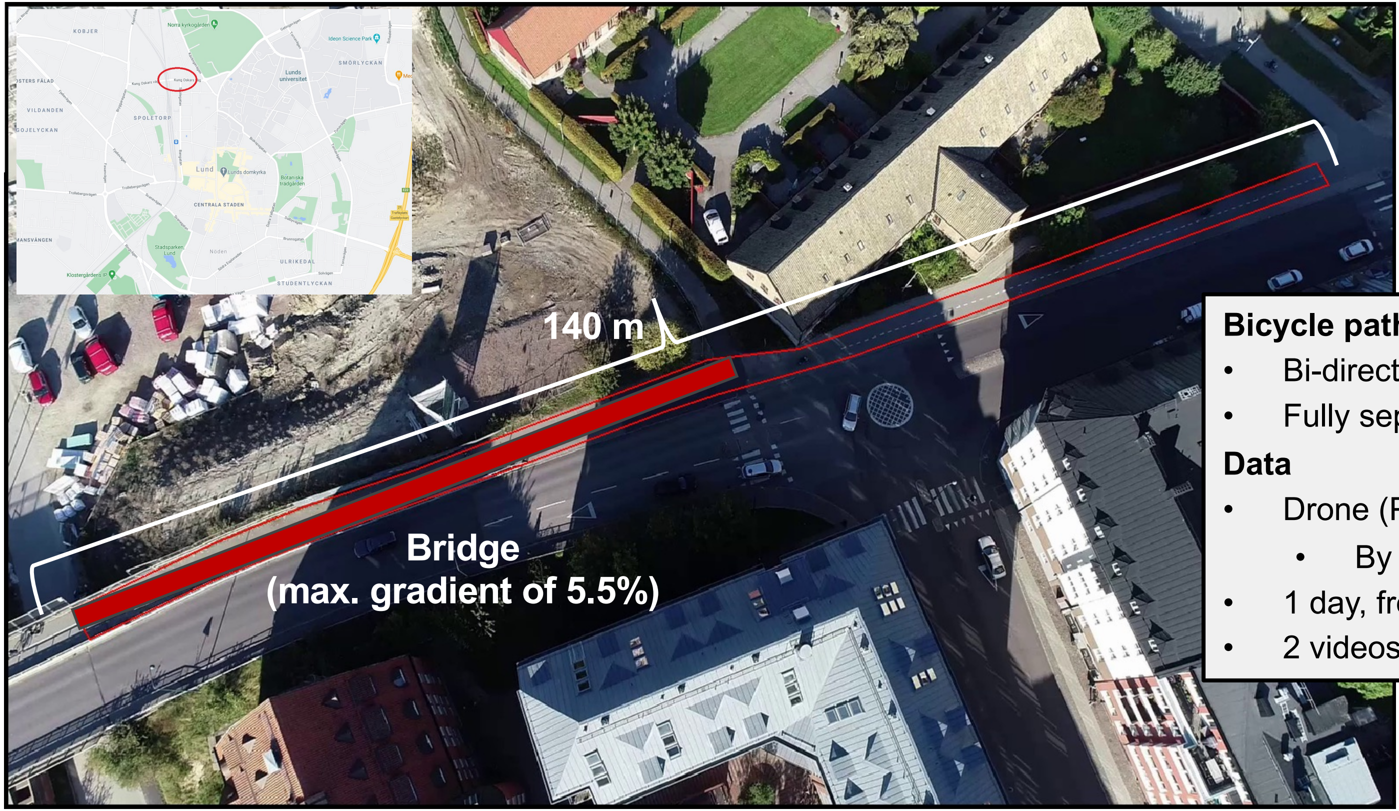


PURPOSE

- To investigate the connection between gradient and the power output in a population of cyclists.
- Towards developing a power-based modelling approach to simulate free-riding on path segments, considering:
  - The impact of gradient.
  - The heterogeneity of bicycle traffic.

DATA COLLECTION

Kung Oskars bro, Lund



Bicycle path

- Bi-directional (3-meter-wide)
- Fully separated from car traffic

Data

- Drone (Phantom 4 Pro V2.0)
  - By Lund University
- 1 day, from 14 h to 15 h
- 2 videos, 20 min each

FINDING FREE CYCLISTS

Free cyclist:

- A cyclist who at no point have a headway < 2 s.

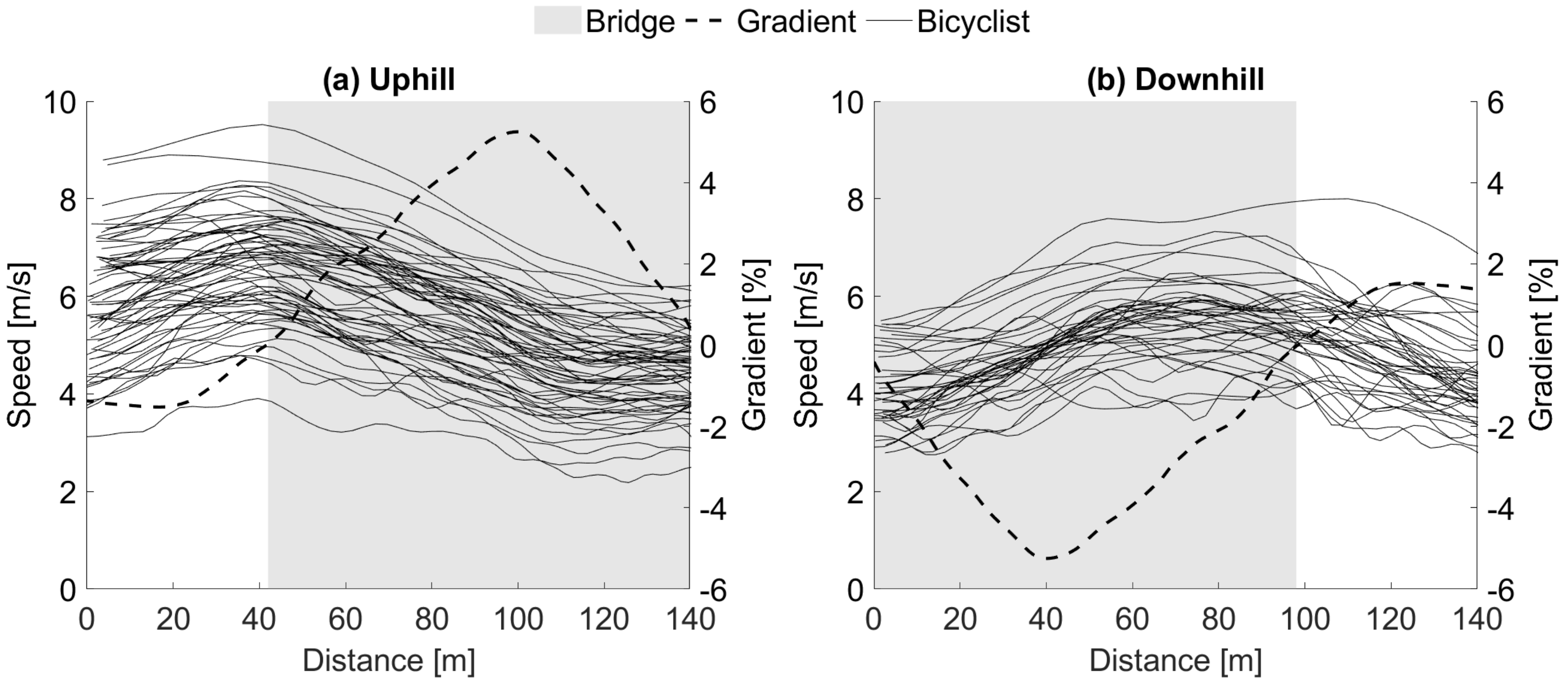
Other criteria:

- Riding on bicycle path
- Riding straight through (no turnings)

Travel direction	All	Free cyclists
Westbound (uphill)	135	**65**
Eastbound (downhill)	86	**42**

Total = 107

SPEED

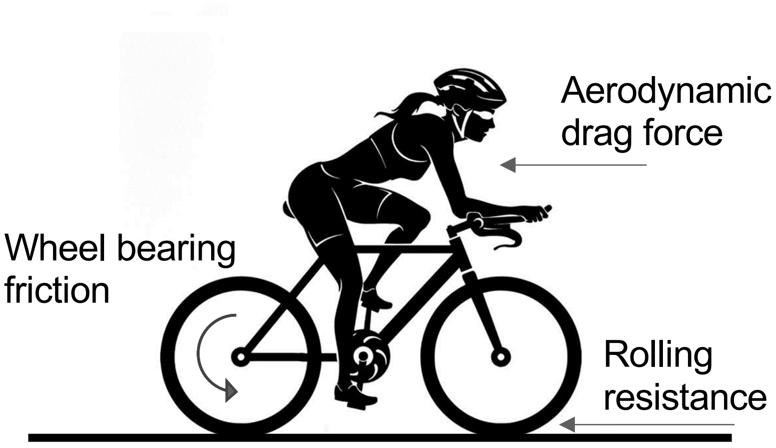


Bridge
Gradient
Bicyclist
(a) Uphill
(b) Downhill
Speed [m/s]
Gradient [%]
Distance [m]
0
2
4
6
8
10
-6
-4
-2
0
2
4
6
0
20
40
60
80
100
120
140

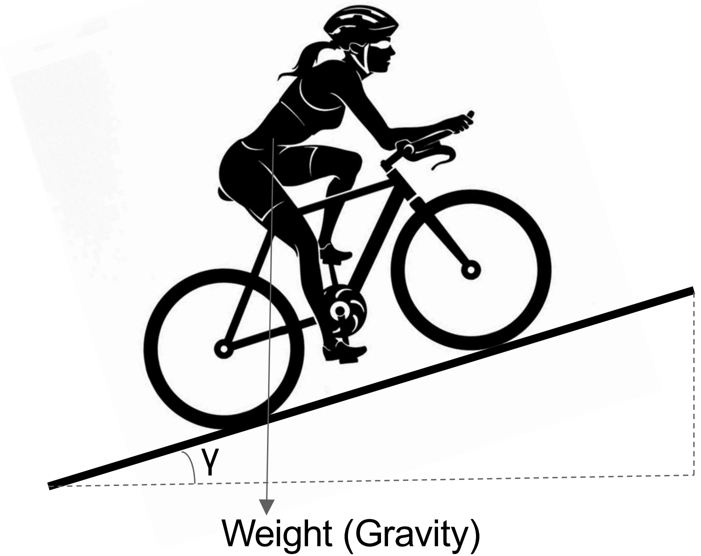
A POWER-BASED MODEL

Martin et al (1998) – To estimate power output considering bicycle dynamics

Free-riding on flat segments



Free-riding on non-flat segments



COMPUTATION OF RELATIVE POWER OUTPUT

Properties equal for all cyclists

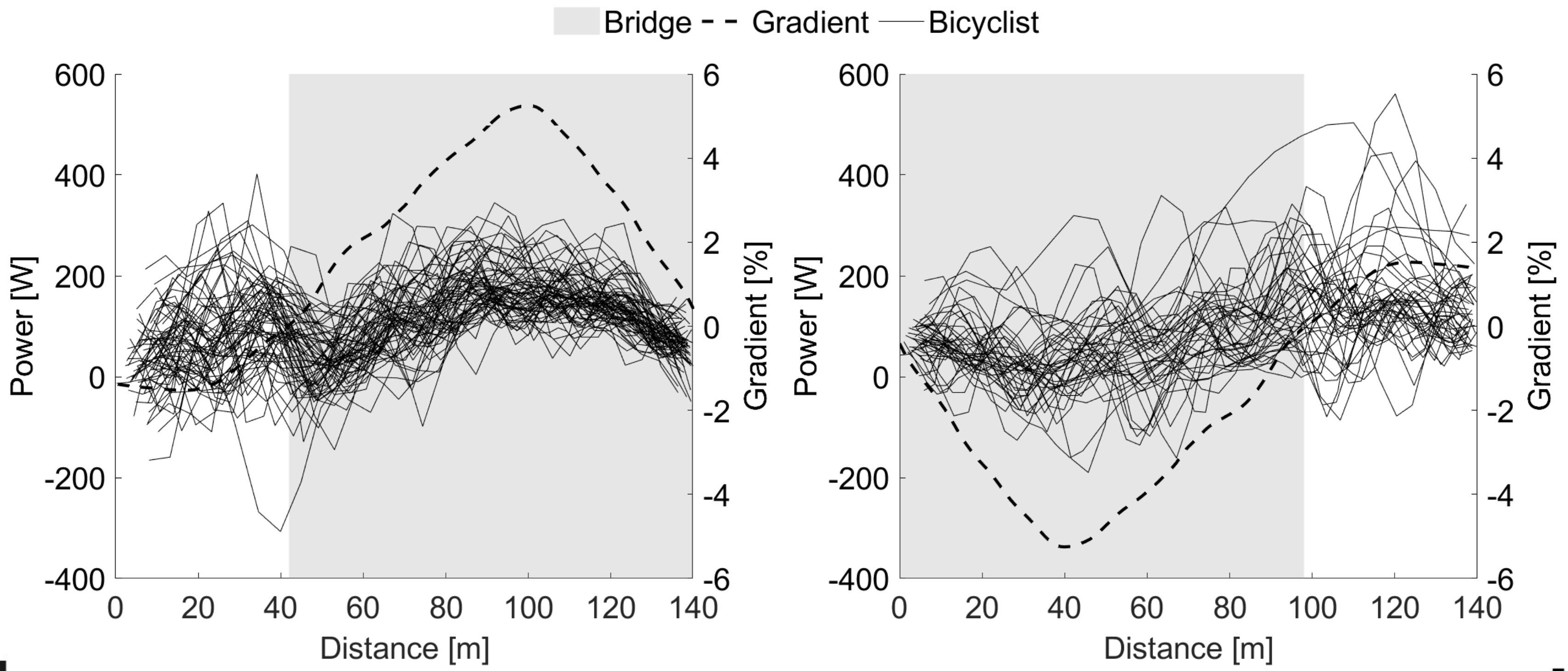
Total mass = weight of cyclist + weight of bicycle

Mechanical properties of the bicycle: frictional losses in the drive chain and wheel bearing systems.

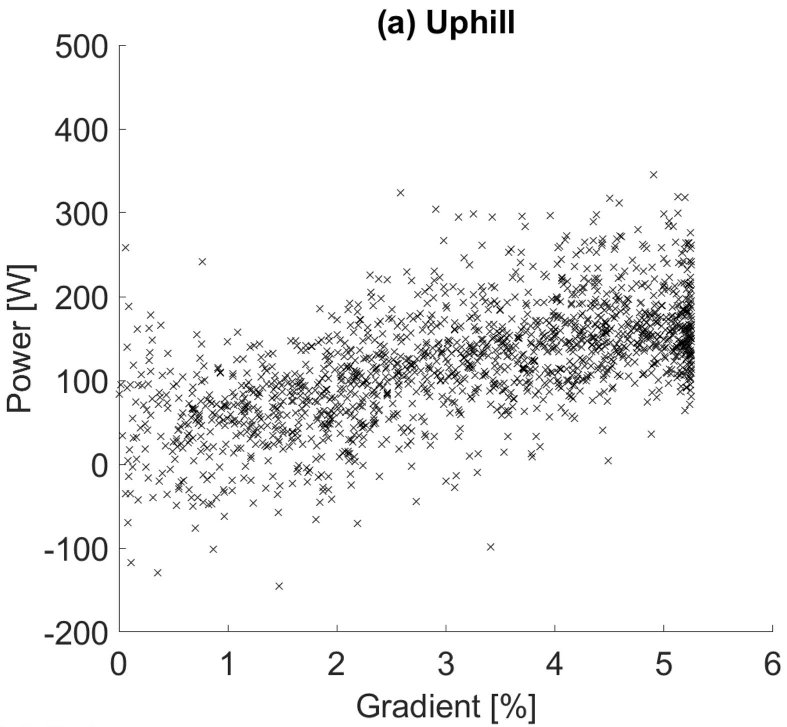
Rolling resistance: coefficient of rolling resistance.

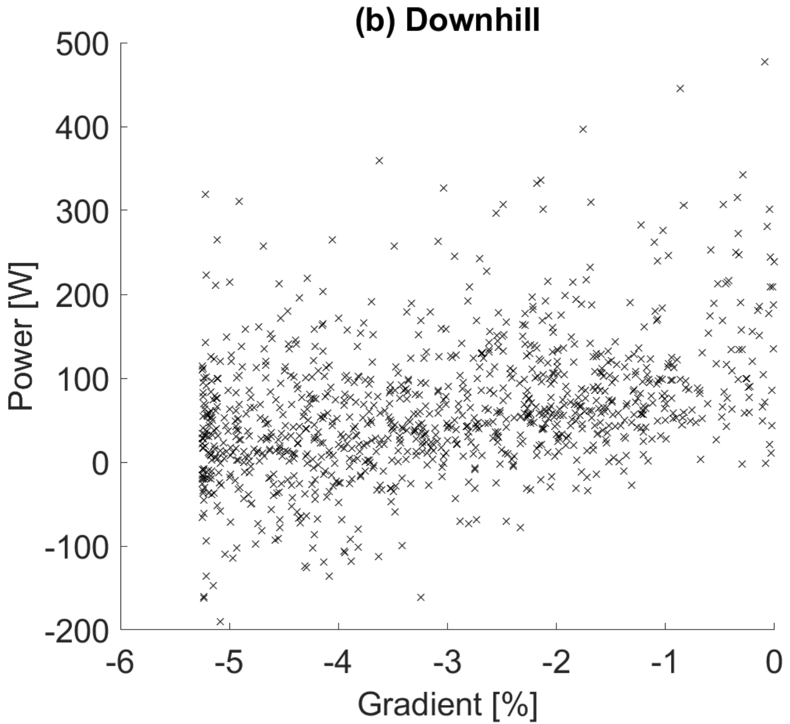
Aerodynamics: air density, drag coefficient, wind speed and direction, etc.

POWER OUTPUT



POWER OUTPUT VS GRADIENT





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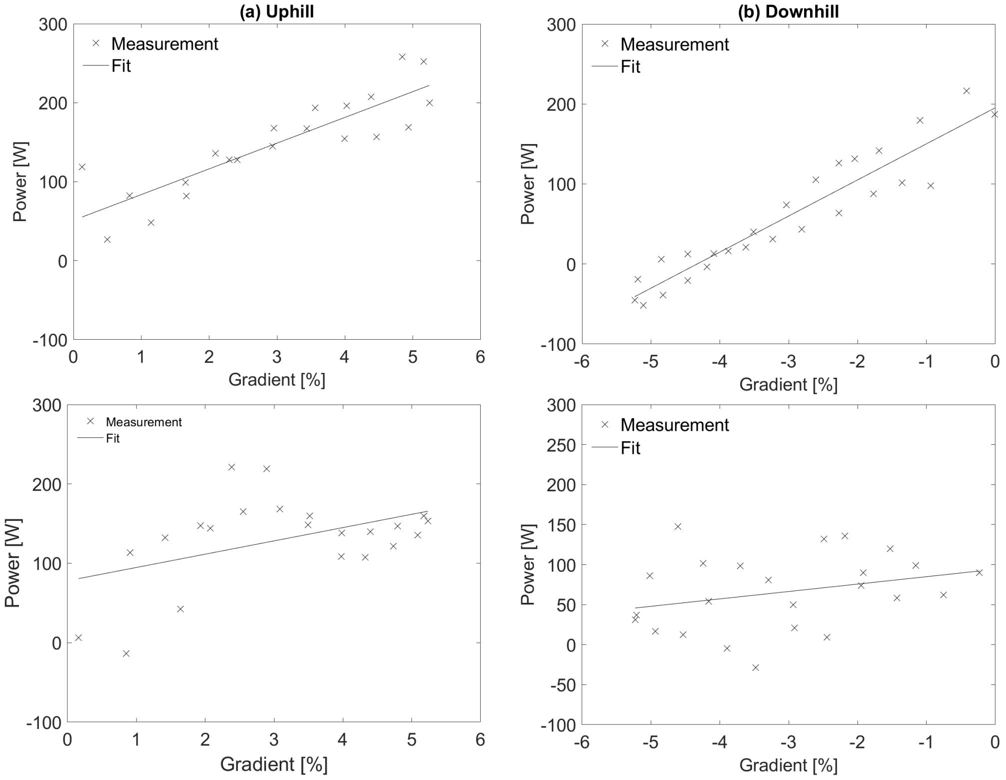
POWER OUTPUT VS GRADIENT (INDIVIDUAL)



MODEL ESTIMATION

- Estimate relative power output as a function of gradient (γ), at current wind speed $(v_a = 5 \text{ m/s})$

$$p_{pedal} = p_0 + p_1\gamma$$

  - p_0 : desired power output
    - power necessary to maintain v_o when $\gamma = 0$
  - p_1: desire (or ability) to ride (or compensate) for the uphill/downhill

- Estimate an individual linear model for each cyclist, with parameters p_0 and p_1

SIMULATION ALGORITHM

1. Compute changes in the kinetic energy (P_k) (conservation of energy)

$$P_k = p_{pedal} - p_{grad} - \sum_{j \in J} p_j$$

Where:

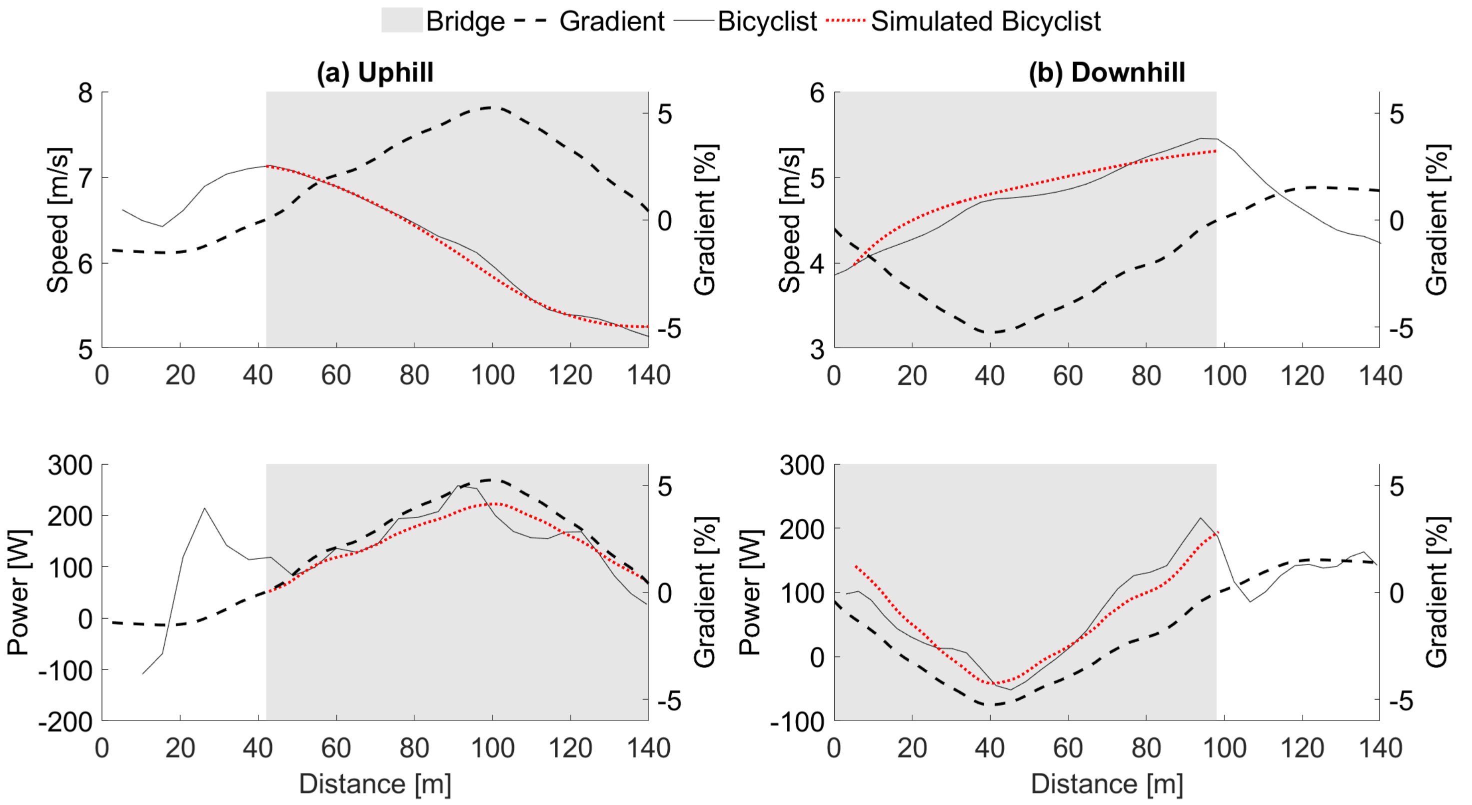
- p_{grad} represents changes in the potential energy, $\gamma(x_i)$
- J is the set of types of losses in power, namely
    - aerodynamic resistance,
    - rolling resistance, and
    - wheel bearing friction

2. Compute speed (v_i) based on kinetic energy equation

3. Update position (x_i)

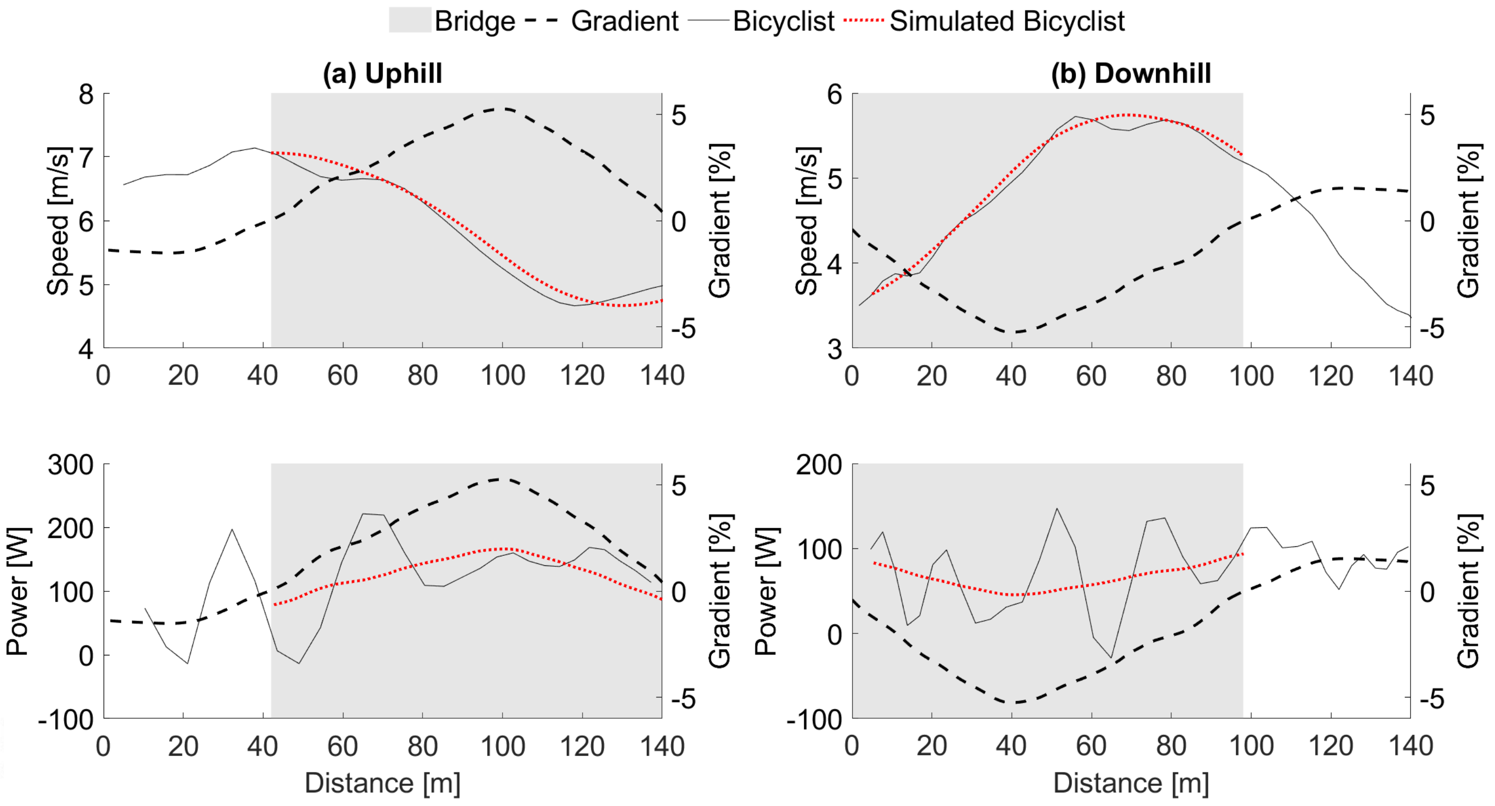
SIMULATION

Cyclists with a high R-Squared model.



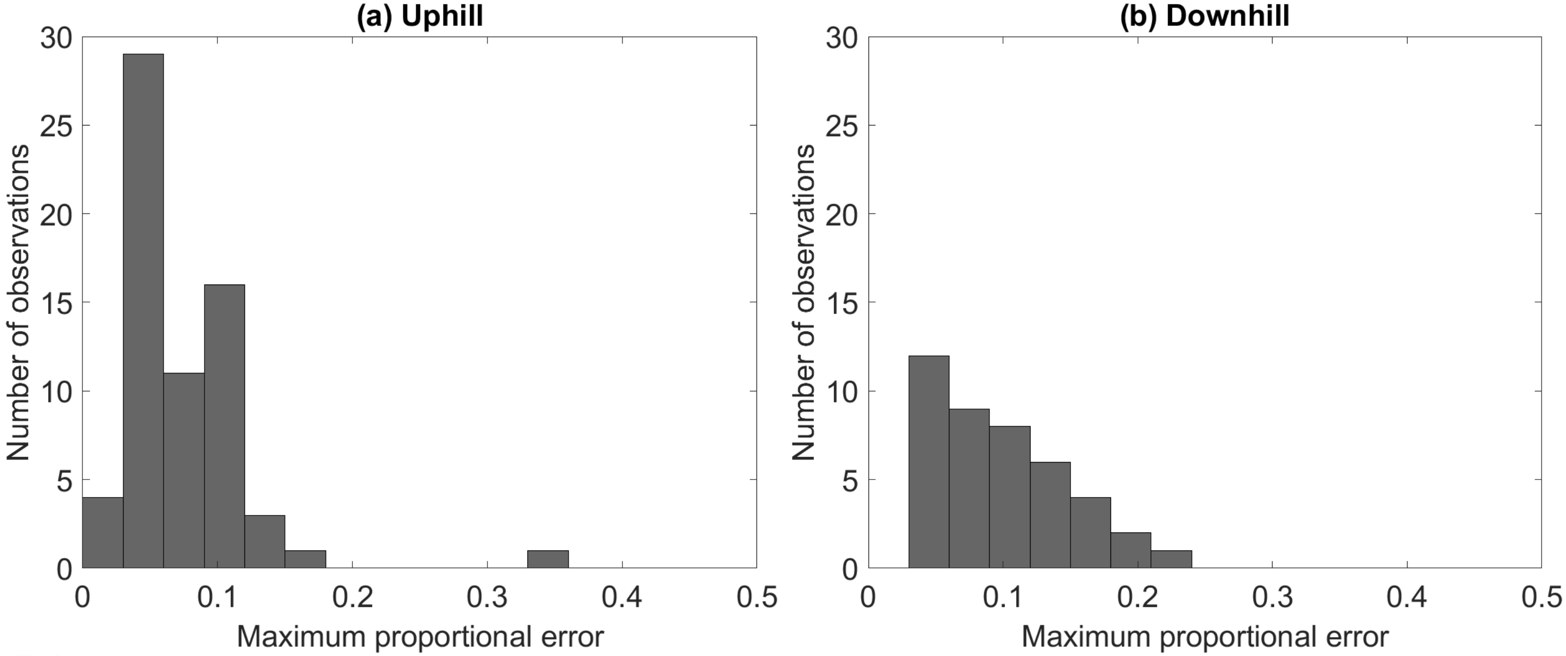
SIMULATION

Cyclists with a low R-Squared model.



ESTIMATION ERROR IN SPEED PROFILES

Based on maximum (proportional) deviation between observed and simulated speed profiles



CONCLUSIONS

- Power is not constant in free-riding on non-flat paths
  - Cyclists adapt to cope with the uphill/downhill
- A linear model of power output as a function of gradient fits well on the uphill
  - … and to some extent on the downhill.
- The impact of gradient may vary greatly among bicyclists.
  - Uncertainties remain due to assumptions to estimate power output.
- A power-based model approach seems suitable for simulating bicycle traffic.

FUTURE RESEARCH

- Domain of applicability of the presented linear model
  - Magnitude and length of the non-flat segment.
- Coasting and braking behavioral patterns.
- Transitions between uphill/downhill (tactical behavior).
- Relation power and energy expenditure (effort).
  - Trade-offs between time/speed and effort.
- Adding other elements of infrastructure/environment in connection to free-riding.
  - Aerodynamic resistance, horizontal curvature, etc.

■ Thanks

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